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1.—PERMIAN PRODUCTINAE AND STROPHALOSIINAE OF WESTERN AUSTRALIA.

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I. INTRODUCTION.

The correlation of beds in geographically distant localities has often been based on the comparison of published lists of fossils. At many times in the history of Australian Geology these comparisons have been made without a re-examination of the specimens concerned:

> "Creatures borrowed and again conveyed
> From book to book—the shadows of a shade."

The first specimens from Western Australia were described in 1883, and at that time one specific name covered a multitude of forms which have now been subdivided into several species. It is thus obvious that if the correlations are to have any value, drastic revision of the naming of many specimens is necessary. This paper, containing complete descriptions of the Permian *Productinae* and *Strophalosiinae* of Western Australia is a small contribution towards that revision.

The present time is opportune for this revision as the work of the geologists of the Freney Kimberley Oil Co. and of Oil Search, Ltd., has increased enormously our knowledge of the geology of the Permian and has made available collections of fossils. I offer my thanks to Dr. Arthur Wade of the Freney Kimberley Oil Co. and to Mr. H. Fletcher of the Australian Museum, Sydney, for the loan of the specimens collected.

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The following abbreviations are used in the text:—

B.M., British Museum (Natural History).

Aus. Mus., Australian Museum.

W.A. Mus., Western Australian Museum.

U.W.A., Department of Geology, University of Western Australia.

G.S.W.A., Geological Survey of Western Australia.

The terminology as used throughout this paper is as defined by Muir-Wood (1928). All measurements of specimens are given in millimetres and the sign + after a number indicates measurement along a broken specimen.

II. MORPHOLOGY AND BIONOMICAL INTERPRETATION THEREOF.

External Features.

The general form of the shells of the *Productinae* and *Strophalosiinae* is concavo-convex dorso-ventrally. There are, however, some exceptions.

Within the group *Productus* sensu lato the concavity of the brachial valve varies from strongly concave as in *Krotovia* to almost flat as in *Waagenoconcha*. The pedicle valve is always convex and usually strongly so. The curvature, as seen in longitudinal profile, may vary but little over the whole profile or may change abruptly. In the latter case the shell is called geniculate when the curvature has increased and fringed or flanged when it has decreased. Fredericks has suggested a classification of the Productids based on the types of visceral cavity produced by the differences in curvature of the two valves. He distinguishes three types.

A. *Productus typici α.* Pedicle valve with regular curvature. Brachial valve flat or gently concave. Visceral cavity deep. *e.g. Waagenoconcha imperfecta* Prendergast.

B. *Productus typici β.* Pedicle valve with regular curvature. Brachial valve concave, following the curve of the pedicle valve. Visceral cavity thin. *e.g. Krotovia spinulosa* (Sowerby).

C. *Productus proboscidei.* Pedicle valve regularly curved or geniculate. Brachial valve geniculate. Development of trail characteristic of the group. *e.g. Productus productus* (Martin).

The terms suggested by Fredericks serve as useful names for the description of visceral cavities, but it is doubtful if they can be used as the diagnostic feature by which to distinguish separate genera. The character of the visceral cavity may or may not be a reflection of important anatomical differences. It is, however, of little importance in modern lamellibranchs as *Pecten,* for example, has one valve (usually the left) flat, while the right valve may vary from slightly convex to rotund. There is here, within the one genus, a great variation in the size of the visceral cavity. The example chosen may not be strictly analogous, however, and where in a large number of specimens the visceral cavity is of the same type, this, in combination with other features, could certainly be used as a feature of diagnostic importance.

In *Aulosteges* the shell has the same form as in *Productus* s.l. Where, however, the area of the pedicle valve is high and reclined, this valve tends to become flattened and the brachial valve is slightly convex, the form approaching to the condition seen in the *Orthotetinæ.* Among the species of *Strophalosia* the form of the shell does not vary beyond the limits already described for *Productus* s.l. In *Etheridgina* the pedicle valve is often flattened by attachment of the whole valve.

The area of attachment in *Strophalosia* and *Aulosteges* raises the question of the position of the shell during life. In *Productus* s.l. the shell lay on the larger pedicle valve with the brachial valve approximately parallel to the substratum and the plane of symmetry vertical. The growth of a trail allowed the animal to obtain its water supply from a level higher than that of the body. Possibly the shell sank by its weight into the substratum and water taken into the body through the trail was cleaner and contained a richer food supply. The trail would also serve as a protection to the animal in providing only a narrow opening at some distance from the vital organs and separated from them by a right-angled bend. In *Strophalosia* the point of attachment is at the apex of the umbo. It is not known for what period of its life the animal was attached, but it seems unlikely, when the small size of the cicatrix is compared with the size of the shell, that this condition of growth prevailed throughout life. However, whatever the length of this period the shell must have grown upwards from the point of attachment at the umbo. In many *Strophalosias,* owing to the geniculated or bevelled character of the interior of the brachial valve the shell develops a small trail. Presumably, when the shell became too heavy to maintain itself in the vertical position it fell on to its heavier pedicle valve, the trail then serving as in *Productus.* An irregular deformation of the umbo, presumably due to attachment, is sometimes seen in *Aulosteges;* the same explanation may be offered in this genus.

The ornamentation of the *Productinæ* and *Strophalosiinæ* is essentially spinose. Spines are developed most frequently on the pedicle valve and rarely on the brachial valve which, where the pedicle valve is spinose, develops pits corresponding in position to the spines of the pedicle valve. The spines may he of one or different sizes, they may be erect, oblique or adherent while their position on the shell may vary from genus to genus. They may be scattered irregularly or show a definite arrangement such as a row along the cardinal margin or separating the ears from the body of the shell. They may occur in concentric or radial rows or show a regular quincuncial arrangement over the whole shell surface. The capacity to develop spines is probably

inherent in the animal, while the degree of their development will depend upon external environmental conditions. Given the condition neeessary for spine development, that is, a plentiful supply of $CaCO_3$, any species will probably develop spines in the same position in all its members. The inclination of the spines to the body snrfaee will depend upon the hardness of the sea-floor, arising at a high angle where the substratum is soft and being adherent where it is hard. In modern lamellibranehs the temperature of the water has a marked effeet on the thiekness of the shell, the Aretic forms having a thiek shell and the warm water forms of the same speeies a shell thin almost to fragility. The differenee between the Irwin forms, thin with short spines of small bore and those from Mt. Marmion, thick-shelled with heavy spines, of *Tæniothærus subquadratus* (Morris) is possibly due to the differenee in temperature of the sea at the two loealities.

Both valves may be ornamented by rugæ and costæ. The rugæ are formed at the growing edge of the shell and are thus in inverse positions in the two valves. Costæ are longitudinal folds perpendieular to the rugæ. Where both are present, the surface is reticulated as seen in the *Dictyoclostus* group; at the points of contaet of the two series of folds an enlarged node may be produced, sometimes giving rise to a spine. Wrinkles are more indefinite than rugæ, they may eross the viseeral disc or be confined to the ears. The lamellæ seen in *Strophalosia* and *Aulosteges* are quite distinct from both rugæ and wrinkles. They are not folds but are the edges of the shell as it was laid down in successive layers. The distinctness of these layers one from another indicates that seeretion of shell substanee was not continuous but intermittent and seasonal, a period of seeretion being followed by a resting phase. The control is a physieal one but the response of the various genera is dependent on the sensitivity of the animal itself and is, therefore, a biologieal faetor.

In the strueture of the eardinal margin these shells show a wide diversity of form. In the *Productus* s.l. group a cardinal area is not ordinarily developed. In *Dictyoclostus callytharrensis* n.sp. however, and in some Indian forms, e.g. *Dictyoclostus indicus* (Waagen) a narrow coneave "area" named by Schuchert and Cooper a ginglymus is often seen on the pedicle valve. It is to be noted that the ginglymus is only seen when the brachial valve has been displaced. This ginglymus is a groove along the cardinal margin of the pedicle valve into which fits the narrow margin of the brachial valve henee greatly inereasing the effieiency of the artieulation of the valves. In the genus *Productorthis* Schuchert and Cooper postulate that the ginglymus has arisen from the degeneration of the area. This explanation cannot hold for *Dictyoclostus,* as the early forms of the genus possess neither an area nor a ginglymus. Whether the ginglymus can, conversely, develop into an area, present information does not allow us to state. It seems unlikely that development would take this course unless teeth are present to take over the function of the ginglymus as an aid to articulation.

Both *Aulosteges* and *Strophalosia* possess a true area though its form is very different in the two genera. In *Aulosteges* it is linear in the earlier species, but rapidly develops among the later species to a high plane triangle produeed ventrally and thus earrying the umbo of the pedicle valve away from the brachial valve. In *Strophalosia* the area is much smaller, remains linear throughout the genus and is produced over the hinge-line so that the umbo of the pedicle valve approaches the brachial valve. A narrower area is present in the brachial valve of *Strophalosia.*

The area in both these genera possesses a distinct pseudo-deltidium and in *Strophalosia* a pseudo-chilidium in the brachial valve. The terms pseudo-deltidium and pseudo-chilidium have not the significance usnally given them in the description of embryonic brachiopods. The division of the area into two lateral parts by the pseudo-deltidium is undoubtedly due to the interruption of the deposit of $CaCO_3$ along the cardinal margin by the projecting ridges, the pseudo-deltidium being that part of the shell filling the space between these ridges. At the places of formation of the ridges there is excess $CaCO_3$ deposit and this projects slightly above and below the level of the area, as Frederick's "delthyrial ridges" above and where the downward projecting ridges are more pronounced they take on the function of and are, teeth. In *Strophalosia* the angle of divergence of the sides of the pseudo-deltidium gives some indication of the angle of divergence of the roots of the teeth though not necessarily of the teeth themselves as these may extend laterally from their roots. That portion of the hinge-area, called, in the brachial valve, the pseudo-chilidium is the posterior root of the cardinal process. The narrow grooves limiting its extent are the internal edges of the sockets. In *Aulosteges,* which has no brachial area, the posterior root of the cardinal process is produced beyond the hinge-line as a flat triangular plate, in the plane of the brachial valve, which partly fills the delthyrium. The pseudo-deltidium of *Aulosteges* may bear spines.

Internal Features.

Brachial Valve.—However the external appearance of the brachial valve may vary on the inside it always has a flat visceral disc with possibly down-turned margins. A medium septum arising at the base of the cardinal process divides the shell into two halves. The septum varies in length from one-half to two-thirds of the length of the visceral disc.

Muscle Impressions.—The adductor muscle impressions lie posterior to the middle of the valve on either side of the median septum. They are dendritic in *Aulosteges* and *Productus* s.l. but non-dendritic in *Strophalosia.* The presence of dendritic muscle impressions in *Aulosteges* and *Productus* s.l. is a reflection of the poorly developed articular apparatus in these two genera. Since the brachial valve is pivoted loosely on the cardinal process it is capable of movement not only in a plane perpendicular to the surface of the valve but also from side to side. This lateral skewing movement would cause a differential movement within the muscle itself, the fibres nearer the centre being less extended than the excentric fibres. A divided muscle would, therefore, be mechanically superior. In examining a dendritic muscle it will be noted that the bunches of fibres have an approximately radial arrangement with the radii on the inside much shorter than those towards the lateral margin. As the central muscles have a shorter pull this arrangment is what would be expected.

In *Strophalosia* the muscle scars are non-dendritic but, except in *Wyndhamia,* are divided into posterior and anterior parts. The anterior adductor is elongated in the longitudinal axis of the shell and lies very close to the median septum while the posterior portion is elongated laterally, lies above and close to the anterior adductor, but extends beyond it. The brachial impressions arise at the lateral terminations of the posterior adductor impressions.

Brachial Impressions.—The brachial impressions are similar throughout the group. In *Strophalosia,* as already noted, they arise at the lateral extremities of the posterior adductors and continue to the lateral margin at an angle to the hinge-line varying from 45°-0°. They then run parallel or nearly so to the lateral and anterior margins to a point about one-third of the width of the shell from the lateral margins when they curve through a right angle towards the hinge-line. This line is followed until the impressions are opposite the end of the median septum where they have another right angle bend to meet at the anterior end of the median septum. In *Productus* s.l. and *Aulosteges* the brachial impressions arise at the anterior end of the dendritic impressions and continue to the lateral border in a course parallel to the hinge-line. When almost at the lateral margin they curve in a wide are and return to the base of the median septum, again running parallel to the hinge-line. In many specimens the returning arm is but faintly seen or may be totally obscured. The interpretations of the brachial impressions have been numerous. They are now described as the attachments of the brachial arms which projected ventrally from them. Muir-Wood (1928, p. 20) has cited some evidence in favour of this view from the minute structure of the impressions. The upward medial bend, where the impressions recede from the anterior margin would correspond, then, to the pallial sinus of the Lamellibranchs, being the region of water intake. The water would be ejected from the apices of the cones and this current would thus have no effect on the basal attachments. The development of a fold in the brachial valve with the corresponding sinus in the pedicle valve would serve further to localise the ingoing and outgoing currents.

Cardinal Process.—In the description of the species the term "trifid" has been used to describe the cardinal process. To avoid misapprehension that term is here defined as referring to a cardinal process which is bilobed in ventral aspect and trilobed in dorsal aspect or which is a modification of this type. The dorsal and ventral aspects are the views of the cardinal process as seen from the brachial and pedicle valves respectively.

To expand this definition the cardinal process of *Aulosteges wangenheimi* (Vern.) may be considered (refer to Fig. 5, p. 34). In this species the cardinal process is perpendicular to the plane of the brachial valve and is supported by two lateral ridges arising from the cardinal ridge. These ridges, which are separated medially by a deep sulcus, give rise to two convex masses, the lobes of the ventral aspect, separated by a depression. The dorsal aspect shows the structure of the process clearly. It has the form of a double-S. The median convexity of this double-S is the central lobe, and the end arms the lateral lobes of the dorsal aspect while the two concavities are the lobes of the ventral aspect. The whole process has the form of an open and indented cone with its apex at the hinge-line. The growth-lines of the structure may be followed round the dorsal face and are parallel to the base of the cone.

All the cardinal processes examined were modifications of this type. Thus in *Aulosteges baracoodensis* Eth. fil. the process is not in such an advanced stage of development. The dorsal aspect shows the process elongated with the lobes becoming distinct some distance from the hinge-line. The ridges of the ventral aspect have remained as ridges and are not enlarged into the convexities seen in *Aulosteges wangenheimi* (Vern.). They are indented posteriorly having a quadrilobed termination.

The variations within *Productus* s.l. are numerous. In the semireticulate group as Muir-Wood (1928, p. 18) says:—

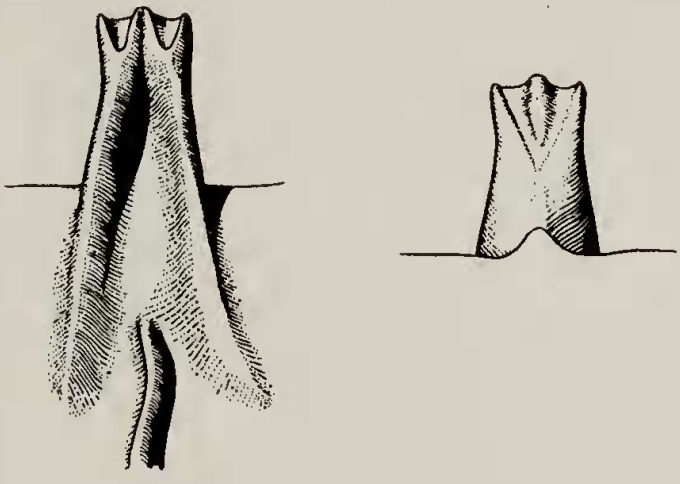

Figure 1.
Cardinal Process of *Aulosteges baracoodensis* Eth. fil. (×3).

"The cardinal process projects beyond the margin of the brachial valve and is divided by a median furrow into two parts which are smooth and rounded; these are continued dorsally as to two curved laminae, separated from the median septum by deep sulci. The dorsal view of the process shows it to be trilobate and transversely striated."

This condition can be readily understood by reference to Figure 2 (p. 15) showing the cardinal process of *Dictyoclostus callytharrensis* n.sp. In this species as in all Dictyoclostids the whole cardinal process is flattened and widened and the lateral lobes have been rotated through nearly 90° until, instead of being parallel to the central lobe, they lie at right angles to it and parallel to the hinge-line.

In *Taeniothaerus, Linoproductus* and *Waagenoconcha* the modification has taken quite a different form, as in these genera the tendency has been for the process to elongate and for the lateral lobes to be distinct and separated from the central lobe (see *Taeniothaerus subquadratus* (Morris), Figure 3, p. 28). The median depression of the ventral aspect is distinct and continues to the apex of the process but the posterior part of the process is now trifid even in its ventral aspect. In *Taeniothaerus* the process is still compact, but in *Linoproductus* (e.g. *Linoproductus cora* (d'Orb.) Kozlowski, fig. 8, p. 14) the lateral lobes have splayed out and the process appears winged. In *Waagenoconcha* (e.g. *Waagenoconcha humboldti* (Waagen), Kozlowski, fig. 9, p. 15) the dissection of the lobes is continued further towards the hinge-line than in the other genera. In the aged specimens Kozlowski found that the median lobe sometimes divided giving what has been described as a quadrilobed cardinal process.

The shells so far considered have had the median septum separated from the cardinal process by a sulcus of varying depth. In the *Strophalosias,* on the other hand, the median septum arises within the cardinal process. The septum swells out between the sockets and completely fills the median depression between the ventral lobes. This swelling is shown in *Strophalosia kimberleyensis* n.sp. (Fig. 8, p. 48) in which a part of the depression may be seen posterior to it. This outgrowth of the median septum would give additional support to the socket plates. The median septum in *Strophalosia etheridgei* n.sp. (Fig. 7, p. 44) is not unduly swollen, but has, nevertheless,

completely obliterated the median depression. On its dorsal face, also, the process of this species is much reduced, faint depressions marking the positions of the dorsal concavities.

Where the median depression is present in the ventral aspect, as in *Aulosteges and Productus* s.l. the depth of this depression is regulated to some extent by the inclination of the cardinal process to the plane of the brachial valve. Where the process is erect the depression is shallow but where it becomes sharply bent over, as in *Aulosteges wangenheimi,* the sulcus is very deep.

Marginal Ridges, etc.—Marginal ridges are sometimes developed in species of this group, for example, *Strophalosia kimberleyensis*. These ridges are always low and not prominent. In some species of *Aulosteges* a pronounced ridge may be developed along the hinge-line, as in *Aulosteges wangenheimi* (see Fig. 4, p. 33). This ridge is placed anterior to the hinge-line.

Pedicle valve.—The muscle impressions of the pedicle valve are of the same general form although they vary throughout the group. The adductors, dendritic in *Aulosteges* and *Productus* s.l., non-dendritic in *Strophalosia*, are median and separated by a groove or a small ridge. The diductors are large, flabellate and longitudinally striate. In some species of *Strophalosia* the ears of the pedicle valve are thickened so that when the shell is closed the ears fit closely one upon the other. This thickening is seen as a flat ledge on the inside of the valve and projects slightly over the visceral cavity.

For a description of the microscopic structure of the shell reference should be made to Muir-Wood (1928, p. 29) and Dunbar and Condra (1932, p. 179).

III. TRENDS IN THE PRODUCTINAE.

Although sufficient data are not yet available for the recognition of lineages, nevertheless some indication of possible trends can be given, based on the fauna of other areas, and these ideas can be applied to the Australian forms.

The table below shows the distribution and characters of the species of *Aulosteges* from the Permian of the Glass Mountains, Texas (King, 1930).

——	Wolfcamp.	Hess.	Leonard.	Word, Delaware Mtn, White Limestone of Guadalupe.
A. wolfcampensis	1b, 2b, 3b	....	....	....
A. medlicottianus	1b, 2b, 3b	1b, 2b, 3b	1b, 2b, 3b	1b, 2b, 3b
A. magnicostatus	....	1b, 2b, 3a	1b, 2b, 3a	1b, 2b, 3a
A. triagonalis	....	1a, 2b, 3a	1a, 2b, 3a	1a, 2b, 3a
A. subcostatus	....	....	1a, 2a, 3b	....
A. beedei	....	....	1a, 2a, 3a	1a, 2a, 3a
A. guadalupensis	....	....	....	1a, 2a, 3a
A. tuberculatus	....	....	....	1a, 2a, 3a

Where 1. radial costae ; b, present, a, absent.
2. concentric wrinkles ; b, present, a, absent.
3. area ; b, low and linear, a, higher and triangular.

As may be seen from the table the shells change from a lirate, concentrically wrinkled form with a low linear area to an unwrinkled form with a high triangular area ornamented only by spines and growth lines.

In India, the evidence of a parallel evolution of *Aulosteges* is not so clear, but is indicated. *Aulosteges medlicottianus* occurs in the lowest fossiliferous beds, the Amb, of the Salt Range, while *Aulosteges* (*Strophalosiina*) *tibeticus,* which has the same characters as *Aulosteges magnicostatus* (concentric wrinkles with radial costae anteriorly) is found in the Middle Productus limestone. *Aulosteges dalhousii* from the Upper Productus Limestone has the same characteristics as *Aulosteges guadalupensis.*

Among the Australian form a similar parallel can be traced. A series of forms appears connecting *Aulosteges baracoodensis* with *Taeniothaerus subquadratus.* The latter species has no concentric wrinkles, a low linear area and the spine bases on the anterior part of the shell sometimes elongated as radial ridges. *Aulosteges baracoodensis* is ornamented by spines and growth lines only, and has a higher triangular area. Both these end forms occur in the Fossil Cliff Beds, Irwin River, although in the North-West Basin *Aulosteges baracoodensis* does not appear until much higher in the sequence. Judged by the rate of change of the American forms *Taeniothaerus subquadratus* would appear in the equivalent of the Hess beds and *Aulosteges baracoodensis* not until the Word. The evolution of the forms may, however, have taken place at different rates in the two areas.

A second shred of evidence of the general stage of development of the Western Australian fauna is provided by the *Dictyoclostus* group. In that genus there is a marked tendency for the area of reticulate ornament to decrease as the species become younger. Thus in *Dictyoclostus semireticulatus* from the Lower Carboniferous of the British Isles the reticulation may be found over the whole shell though not as clearly marked anteriorly. In the Permian species, however, the reticulation is confined to the posterior part of the shell. *D. spiralis, indicus, vishnu, aratus* and *subcostatus* is an ascending stratigraphical series from the Salt Range (Waagen 1884) and shows a gradual decrease in the area of reticulation of the species in the order named. The Western Australian shells, *Dictyoclostus callytharrensis,* have the reticulation covering but a small area of the valve and possess a ginglymus while the ears are separate from the flanks. All these features are seen only among the younger members of the genus.

IV. CLASSIFICATION.

Family **PRODUCTIDAE** Gray, 1840.

In his original description of the family, Gray included the genera *Productus, Strophalosia, Chonetes, Leptaena, Orthis, Strophomena* and *Calceola.* King (1846, p. 94) restricted the family to those shells "distinguished by the form of the ovarian spaces and the presence of spines," and excluded the genera *Strophomena, Orthis, Leptaena, Chonetes* and *Calceola.* Gray (1848, p. 438) was opposed to this restriction and enlarged the family to its original content. Gray's opinion, however, was not widely accepted, and King's diagnosis became the diagnosis of the family.

It was accepted thus by Waagen (1884, p. 611) who said:—

> "the most striking character is the existence of reniform prominent ridges on the inside of the dorsal valve, a character which in this strong and distinct development, is entirely restricted to the *Productidae*."

Waagen subdivided the forms so characterised into two sub-families, *Chonetinae* and *Productinae*.

The *Chonetinae* were characterised by the presence of teeth and a cardinal area in the pedicle valve and of non-dendritic muscle impressions. This sub-family included the genera *Chonetes, Strophalosia, Chonetella* and *Daviesiella*. Most of these forms are free.

The *Productinae* were defined as Productids in which the pedicle valve is without cardinal teeth and the adductor muscle impressions are dendritic. Some of the forms are fastened by the entire pedicle valve or by spines. Waagen placed the genera *Aulosteges, Productella, Productus* and *Marginifera* in this sub-family.

Schuchert (1913, p. 389) changed the emphasis in King's diagnosis and defined the *Productidae* as "*Strophomenacea* with hollow anchoring spines."

Schuchert also altered the content of the sub-families by using the means of attachment of the shell as the main diagnostic feature. Thus the *Chonetinae* became

> "Productids with a few anchoring spines restricted to the ventral cardinal margin,"

and the *Productinae*

> "Productids with the anchoring spines more or less abundant over the entire ventral and sometimes also over the dorsal valve,"

while he founded a new sub-family the *Strophalosiinae* to include

> "Productids anchored to foreign objects by spines or by most of the ventral shell."

Such a division of the *Productidae* is purely arbitrary and while it groups together forms superficially alike, makes no allowance for a similarity of external form due to growth under similar environmental conditions. The sub-family *Strophalosiinae*, for example, includes the genera *Chonopectus, Strophalosia, Aulosteges* and *Etheridgina*.

Strophalosia King, the type genus of the sub-family is an attached form, being cemented by the umbo of the pedicle valve and/or by spines. It has a well-developed area on each valve, non-dendritic muscle impressions and strong teeth. *Etheridgina* possesses an area only on the pedicle valve, teeth may be developed and the shell is cemented directly by part or the whole of the pedicle valve and by spines. The muscle impressions are as in *Strophalosia*.

The genus *Chonopectus* Hall and Clarke is represented by a single species *Chonopectus fisheri* Norwood and Pratten from the English River beds of the Kinderhookian (equivalent to K beds, Lower Carboniferous) of Burlington, Iowa, U.S.A. This species is essentially a small *Chonetes* with a distinctive ornamentation and attached at some period during its life history. It is a restricted form, both geologically and geographically.

Aulosteges Helmersen is distinct from *Strophalosia* in the possession of dendritic muscle impressions. The pedicle valve carries an area, usually high, while that of the brachial valve is small or absent. The articulation is weak, the pedicle valve being without teeth.

It is obvious, then, that within his sub-family *Strophalosiinae* Schuchert has included forms very different in structure. Its attached habit seems an insufficient reason for the separation of *Chonopectus* from those forms, the *Chonetinae,* to which it is closely related, and Schmidt's placement of it (1929, p. 21) in that sub-family must be regarded as the more correct. *Aulosteges,* both in the possession of dendritic muscle impressions and in the pattern of the brachial impressions, approaches more closely to the *Productinae* than to *Strophalosia* and its replacement in the *Strophalosiinae* would seem a more natural position.

It is admitted, however, that little is known of the derivation of *Aulosteges* and *Strophalosia.* Licharew (1934 (a), p. 509) has, on the ground of insufficient evidence for their separation, abolished the sub-families and included all the genera in *Productidae.* He reverts to King's diagnosis and defines the family as

> "Shells free, attached by spines or cemented directly. Dorsal valve flat or concave. Cardinal margin straight. The whole surface or only the shoulders of the ventral valve bedecked with hollow spines. Cardinal process prominent. Dorsal valve with reniform brachial impressions."

To *Productus* sensu lato, *Chonetes* sensu lato, *Strophalosia, Productella, Aulosteges* and *Etheridgina* he adds *Teguliferina* and *Scacchinella.* Dunbar and Condra (1932, pp. 189, 191) and Diener (1927, pp. 30 and 31) also included these genera in the *Productidae.*

Scacchinella Gemmellaro and *Teguliferina* Schellwien are the genera intermediate in character between *Aulosteges* and *Productus* respectively and the *Richthofeniidae.* These genera, however, possess characters which would ally them to the *Richthofeniidae* rather than to the *Productidae. Scacchinella* and *Aulosteges* possess in common the high produced area (higher and more produced in *Scacchinella*) and the method of attachment by the tip of the area. *Scacchinella* is quite distinct, though, in the possession of a well-developed median septum in the pedicle valve and in the character of the cardinal process with its supporting rods. In these characters it approaches *Richthofenia. Teguliferina* in which the productoid characters are still recognisable, resembles closely the *Richthofeniidae* in its mode of growth and in the operculiform character of the brachial valve. It seems reasonable to assume that the peculiar characters of *Richthofenia* are in part a result of its mode of growth and therefore that *Scacchinella* and *Teguliferina,* as the possible forerunners of a group so distinctive as the *Richthofeniidae,* should be included in that family.

A different method of approach to this subject of the classification of the *Productidae* has been used by Sutton (1938), with astounding results. As he points out, the shape of the visceral cavity as a diagnostic feature has been given prominence in Productid literature although no author has attempted a classification based upon that feature. Sutton has. He divides the Mississippian *Productidae* into two sub-families, the *Productellinae* and the *Productinae.* The *Productellinae* have a thin visceral cavity of the type described by Fredericks as *Productus typici* β, and include the genera

Leptalosia, Strophalosia, Productella, Gigantella and *Productina* Sutton. The remaining Productid genera of the Mississippian rocks are grouped as the *Productinae* and possess in common a "large and medium to deep visceral cavity—Frederick's *Productus typici* ∝ ."

This cannot be regarded as a biological or palaeontological classification; it is as Sutton (p. 538) says, "a classification by which different forms may be recognised," in other words, a key, and a key only for the Mississippian *Productidae*. Sutton supports this "classification" by reference to one now being worked out by Stoyanow, who is using as a diagnostic feature the character of the cardinal process, whether trifid or bifid. Examination of the Australian Productids shows that all have essentially the same type of cardinal process, but Stoyanow will doubtless define his terms more accurately when his paper is published.

In the classification which follows the author has tried to group closely related forms together, and finds that in so doing he has reverted largely to Waagen's original diagnoses of the sub-families while following Licharew in the definition of the *Productidae*.

Family *Productidae* Gray 1840. Synopsis of the contents of the British Museum, 42nd Edition, p. 151.

Shells free, attached by spines or cemented directly by pedicle valve. Cardinal margin straight. Surface ornamentation of spines over whole or part of shell. Brachial valve with reniform brachial impressions and median septum. Cardinal process prominent.

Sub-family 1. *Chonetinae* Waagen 1884. Salt Range Fossils, I. Productus-Limestone Fossils: IV (fasc. 3) Brachiopoda, *Pal. Ind.* Ser. XIII, p. 612.

Productids with large spines only along cardinal margin of pedicle valve. Cardinal area and teeth in pedicle valve. Muscle impressions non-dendritic.

Genera. *Chonetes* sensu lato.
Chonopectus.
Daviesiella.

Sub-family 2. *Productinae* Waagen 1884, op. cit., pp. 612, 613. Productids with dentritic muscle impressions and without teeth. Hollow spines present over whole or part of shell.

Genera. *Productus* sensu lato.
Productella.
Aulosteges.

Sub-family 3. *Strophalosiinae* Schuchert 1913, in Zittel K., Textbook of Palaeontology edited by C. R. Eastman, 2nd edition p. 391.

Productids attached by spines and by part or whole of the pedicle valve. Ornamentation usually spinose. Muscle impressions non-dentritic. Pedicle valve with cardinal area and teeth.

Genus. *Strophalosia.*
Heteralosia.

V. DESCRIPTION OF SPECIES.

DICTYOCLOSTUS Muir-Wood emend.

1930. Muir-Wood, *Ann. Mag. Nat. Hist.* (10) V p. 103.
Genotype.—Original designation. *Anomites semireticulatus* Martin (in part). Petrifacta Derbiensia, Wigan 1909, p. 7, pl. xxxii, figs. 1, 2; pl. xxxiii, fig. 4.

Diagnosis.—Shell elongate or quadrate in outline, hinge wide: ginglymus may be present. Pedicle valve convex or geniculate; visceral disc with semi-reticulate ornamentation; trail costate, costae may bear spines both on trail

and visceral disc; rows of spines on ears and cardinal slopes; diaphragm absent. Brachial valve concave or geniculate; marginal ridges prominent, extending along hinge. Hinge teeth and sockets not developed.

Range.—Carboniferous and Permian.

Remarks.—The diagnosis has been emended to include semireticulate productids with a ginglymus (see p. 9). The Western Australian, Timor and Indian species which would normally be placed in this genus are sometimes found to have a ginglymus though agreeing in other particulars with species of this genus. Where the margin is interrupted by the cardinal process, the ginglymus is notched to give the "delthyrium," into which the cardinal process fits, as previously suggested by Dunbar and Condra (p. 18). Below this notch and on each side, thickened ridges which gradually die out laterally, articulate with the transverse ridges of the brachial valve. As would be expected, the ginglymus is not seen if the two valves fit tightly, but is only exposed when the brachial valve is slightly displaced. This was proved in a specimen (S.M. No. 3604) of *Dictyoclostus indicus* (Waagen) from the Salt Range; it possessed both valves, and was without an area, but showed an internal groove in that position when the brachial valve was removed.

The ginglymus has been noted in one other genus, *Productorthis* of Schuchert and Cooper (1932, p. 83). In *Productorthis,* Schuchert and Cooper believe that the ginglymus has arisen from the reduction of the area. In Productids it seems more likely that the area arose from the ginglymus.

The Permian species of *Dictyoclostus,* as far as can be seen from a study of the literature, differ from the Lower Carboniferous species in the restriction of the reticulation to the posterior part of the shell, the separation of the ears from the flanks and the possession of an articulating "area."

The larger Western Australian members of the genus *Dictyoclostus* are undoubtedly closely related, probably in the same way as the *spiralis-subcostatus* group of the Salt Range, and it is only lack of sufficient material which prevents the appreciation of their relationships.

Dictyoclostus callytharrensis sp. nov.

Pl. i, figs. 1-7, Pl. ii, fig. 1.

1903.—*Productus semireticulatus* Martin, Etheridge, jun., p. 18, pl. ii, figs. 3-5.

1907.—*Productus semireticulatus* Martin, Etheridge, jun., p. 29.

1910.—*Productus semireticulatus* Martin, Glauert, p. 87.

1924.—*Productus semireticulatus* Martin, Chapman, p. 36, specimens Nos. 2746, 2748.

1931.—*Productus semireticulatus* Martin, Hosking, pp. 8, 22.

Types.

Syntypes.—G.S.W.A. 1/4967 (b), ½ mile west of Callytharra Spring, Wooramel River District; Callytharra Limestone.

Paratypes.—G.S.W.A. 1/4967 (a), same locality and horizon.

Other specimens.—U.W.A. 12400, Fossil Cliff, Irwin River; Fossil Cliff horizon.

G.S.W.A. 1/4668, south bank of Wooramel River, ¼ mile above Callytharra Spring; Callytharra Limestone.

G.S.W.A. 1/4654.

Aus. Mus. F 36507, 36508, Barragooda Pool, Arthur River, North-West Division. Callytharra Stage.

Aus. Mus. F 36237, Jimba Jimba Station, left bank of Gascoyne River, near Winnemia, North-West Division. Byro Stage.

Aus. Mus. F 38147, 1½ miles west of Williambury-Middalya Gate, Middalya Station. Callytharra Stage.

Diagnosis.—Shell large, semicircular in outline, greatest width at hinge-line; ears large and reflexed, offset from flanks, flanks convex to steep. Pedicle valve sinuate, regularly curved through 270°. Visceral disc occupying about half curvilinear length of valve, rugae and costae regular and equally prominent on visceral disc, costae becoming irregular on trail, two or more coalescing to form irregular folds; rugae absent on trail. Small spines, quincuncially arranged, arising at intersection of costae and rugae, with larger spines, more widely spaced, on rest of shell. Row of spines between ears and flank and row along cardinal margin.

Brachial valve geniculate; ornamentation as in pedicle valve.

The size of the specimens is shown by the table:—

——	Syntypes.		Paratypes.		Largest spec., Irwin R.—12400.
Length of hinge-line	59	59	58	44+	49+
Height	37	38	33+	33+	46+
Curvilinear length	70	71	50	50	95

Shells too crushed to allow measurement of thickness.

Description of the syntypes.—Shell semicircular in outline with the hinge the greatest width of the shell.

The pedicle valve is curved through an angle of 270°. The transverse curve of the valve is a high arch with almost vertical sides and a shallow median depression. A shallow sinus arises at about the middle of the visceral disc and continues forward, becoming shallower and finally disappearing on the trail thus leaving the margin of the valve entire. The ears are large and reflexed; each is separated from the body of the shell by a sulcus, and this is flanked by a fold bearing a row of spines (3-4). A second row of spines runs parallel to the hinge-line and close to it. The semireticulation is marked on the visceral disc, covering 35 mm. along the curvilinear length, the costae and rugae being equally prominent. The costae cannot be traced to the tip of the umbo, where they have been probably removed by weathering, but traces of them can be seen on the ears. They increase in number on the visceral disc both by division and by interealation: no increase takes place on the trail and the costae lose their height, remaining scarcely elevated. The rugae are closely spaced near the umbo, becoming farther apart posteriorly. The spines on the visceral disc are small and oblique and arranged in approximate quincunx, each spine arising from a node at the intersection of a ruga and a costa. Spines do not arise from all the nodes. As the spines are regularly spaced and the number of costae increases anteriorly, there is some irregularity, but every fourth to sixth ruga bears spines, these being separated by eight or more costae. The larger spines on the trail also tend to quincuncial arrangement. Below each on the trail is a fold which replaces the two or more costae above each spine, this folding being independent of the costae, though two or more are absorbed on each fold.

The brachial valve is strongly geniculate. The ornamentation differs from that of the pedicle valve only in the absence of spines. The pits, which replace the spines on this valve, are not placed opposite them, but appear anteriorly. This is particularly noticeable in the row of pits on the sulcus separating the ears. No trace of a cardinal area has been observed on this valve.

The interior of the valve is not seen on the syntypes.

Description of the paratypes—Internal features.—The paratypes show the ginglymus more clearly than either of the syntypes. It is divided by a wide triangular notch. The cardinal process of the brachial valve projects but a little above the level of the hinge as a truncated triangular ridge.

Internally the muscles of the pedicle valve are those characteristic of the genus, longitudinally striated diductors enclosing dendritic adductors, the place of insertion of the muscle much thickened.

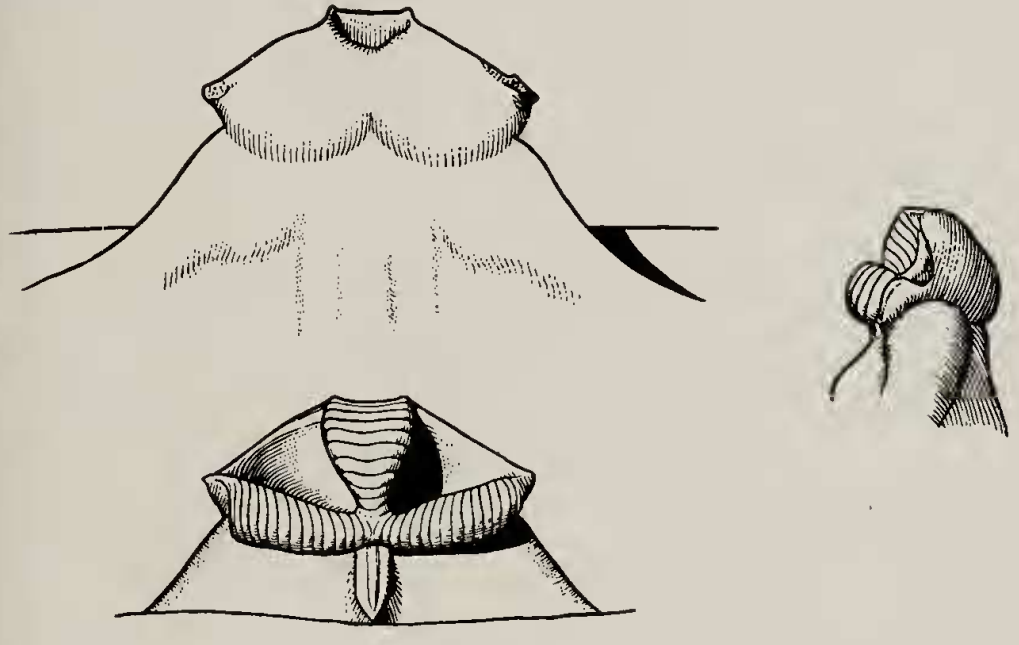

Figure 2.
Cardinal process of **D. callytharrensis** sp. nov. (x6).

Variation within the species.—The topotypes of this species show marked variation in the depth of the sulcus between the visceral disc and the ears. When the sulcus is shallow and not pronounced the rugae extend on to the ears so that these are semireticulate. This extension of the semireticulation has an effect on the size of the auricular spines, since where the rugae are present the spines are small and similar to those of the visceral disc, these replacing the larger spines seen in specimens with a deep sulcus. Recognising this as a variation within the species it is then possible to include the two forms distinguished by Hosking (1933, p. 46) in the one species.

A second variable feature of the specimens is the extent of the semireticulation along the curvilinear length of the shell. Although owing to the crushing of many of the specimens it is difficult to determine the original shapes, it would seem that rugae are not developed after there is a change in the direction of growth, even where this does not amount to a geniculation. This relation between the shape of the shell and the ornamentation probably

exists throughout the semireticulate group. *Dictyoclostus semireticulatus* (Martin), for example, has semireticulate ornamentation throughout its growth, and no change takes place in the curvature.

The Irwin River specimens show the same range of variation as those from the type locality.

Comparison with other species.—The specimens of this species have little in common with *Productus* (*Dictyoclostus*) *semireticulatus* Martin s. str. to which species they have been previously assigned. They differ in having the brachial valve geniculate, the rugae restricted to the visceral disc, the arrangement of the spines on the visceral disc and the division of the ears from the flanks. Briefly the only characteristic common to both species is the presence of semireticulate ornamentation.

The species has much in common with Upper Carboniferous and Permian forms of India and China. It probably occurs in Timor (Basleo) as Broili's figures and specimens (1916 pl. cxvi figs. 14-16) show the same characteristics as the Australian species and Broili gives a reference to Etheridge (1903) in his synonymy. Of the Chinese specimens P. *taiyuanfuensis* Grabau as figured by Chao (1927 p. 30 pl. i fig. 10; pl. ii figs. 1-12; pl. viii fig. 16) from the Taiyuan Series is very close to *D. callytharrensis*. The costation of the Chinese shells is much coarser (the costae vary from 0.5 to 1.3 mm. in width as compared with 0.3 to 0.5 mm.), the larger spines are more numerous and more closely spaced, particularly the row along the inner edge of the ears where each spine touches its neighbour.

D. callytharrensis is undoubtedly related to the *P. spiralis-subcostatus* group from the Salt Range. Frech first suggested that the forms *P. spiralis* and *P. indicus* were possibly the younger and older specimens of the same species, and Broili supported this. More lately Cowper Reed (1931 p. 2) has suggested that the whole group, *P. spiralis, indicus, vishnu, aratus* and *subcostatus* are probably all members of one species group. The nearest form of this group to *P. callytharrensis* is *P. indicus,* but the Western Australian specimens may be distinguished from that species by the tendency in the Indian species for the costae to converge towards, and disappear in, the sinus. Also the spiral arrangement of the costae on the ears cannot be seen in the Australian specimens. The costation is much coarser in *P. indicus* (7 costae in 10 mm., 10 mm. from the umbo).

Dictyoclostus callytharrensis var. **wadei** var. nov.

Pl. II., figs. 2-4.

Holotype.—U.W.A. 20453, ferruginous limestone, two miles east 10° south of Mount Nicholson, Kimberley Division; Nooncanbah Series.

Topotypes.—U.W.A., A.58, A.59, A.65, same locality and horizon.

Diagnosis.—Shell as in *Dictyoclostus callytharrensis* but with approximately hexagonal outline and arched umbonal region. Ears reflexed but not offset from flanks. Pedicle valve sinuate, with semireticulation on almost one-third of curvilinear length of valve, costae irregular, prominent and enlarged on trail, converging towards sinus. Brachial valve unknown.

Description.—The holotype of this variety is a weathered and decorticated specimen. It is 63.7 mm. wide at the hinge-line and 54.5 mm. long. The semireticulate ornament of the visceral disc is badly worn, but probably occupied about 34 mm. along the curvilinear length. The ears, though reflexed, are continuous with the anterior margin of the valve. The trail is ornamented

by large costae, variable in width, bearing large spine bases; these show no regular arrangement. The costae tend to approach and disappear in the sinus. Two large spines are on the ears and three on the flanks just above the angle separating the ears. There is no enlarged rib or hollow on which they are placed. The umbo is rounded and barely overhangs the hinge-line. The ginglymus, if present, is obscured by matrix.

Variation within the species.—Owing to the paucity of specimens (5) it is impossible to determine the limits of variation.

Comparison with other species.—This variety differs from *D. callytharrensis* in the shape of the ears (here continuous with the anterior margin but in *D. callytharrensis* distinct and joining the lateral margin about halfway down the flanks), the greater convexity of the flanks and the invariable appearance of a well-marked sinus in the pedicle valve. The folds, too, in this species are enlarged costae and not formed, as in *D. callytharrensis,* by two or more costae coalescing. In all these particulars they approach *P. indicus* Waagen, but continually differ in the much finer ornamentation.

It is possible that this form should constitute a distinct species, but in the absence of any definite knowledge of their stratigraphical relations to *D. callytharrensis* I have preferred to designate them as a variety. They are obviously closely related to *D. callytharrensis* mihi.

Dictyoclostus gratiosus (Waagen).

Pl. ii, figs. 5-7.

1884.—*Productus gratiosus* Waagen, p. 691, pl. lxxii, figs. 3-7.

1893.—*Productus gratiosus* Waagen, Rothpletz, p. 76, pl. x, fig. 15.

1916.—*Productus gratiosus* Waagen, Broili, p. 12, pl. cxvi, figs. 4, 5, 7-13.

1927.—*Productus gratiosus* Waagen, Chao, p. 44, pl. iv, figs. 6-10.

1928.—*Productus gratiosus* Waagen, Hamlet, pp. 19, 20.

Material.—Aus. Mus.

F 37567—¼ mile east of shale outcrop, Minilya River, North-West Division, Wandagee Stage.

F 37568—¼ mile west of shale outcrop, same locality and horizon.

F 37569-37571—Bank of Minilya River, same locality and horizon.

Diagnosis.—Shell small to moderate in size, outline hexagonal. Pedicle valve inflated, geniculate; brachial valve concave. Greatest width at hinge-line, ears small and pointed.

Pedicle valve with flat visceral disc, shell geniculate. Ornamentation reticulate on visceral disc, costate on trail. Strong sinus. Small erect spines scattered on trail and alar extremities. Costae converging towards sinus.

Brachial valve concave with median fold. Ears excavated, smooth or lightly costate. Convergence of costae towards fold. Valve with reticulate ornamentation on posterior part of shell.

Internal characters not known.

Description.	Dimensions.				
Length of hinge-line	27·8	18·0+	16·6+	25·0	14·5+
Height	17·7	13·7	16·1	15·8	11·7+
Curvilinear length of pedicle valve	30·9	21·0	32·3	31·8	21·0

The shells are small to moderate in size as may be seen from the table of dimensions. They have an irregularly hexagonal outline when viewed from the pedicle side, with the hinge-line the greatest width of the shell.

The pedicle valve has a flattish visceral disc which, following the geniculation of the shell, passes into a regularly curved trail. Transversely the shell arch is high, indented medially by a strong median sinus and falling gradually to the lateral margins in a slightly convex slope. The umbo is small, pointed and slightly overhanging the hinge-line. The ears are small and pointed, they have a convex profile in longitudinal section. The ornamentation is reticulate on the visceral disc, the reticulation sometimes irregular due to the enlarged rugae on some specimens. The rugae do not develop anterior to the geniculation, the trail carrying costae and scattered spine bases. The latter are rarely numerous, not more than 4 or 5 being present. The costae converge slightly towards the sinus giving a very distinct and characteristic appearance to the shell.

The brachial valve is trapezoidal in outline, the long straight hinge-line and the anterior margin being the parallel sides. It is regularly concave with a median fold which expands towards the anterior margin. The ears are excavated to fit tightly with those of the pedicle valve. The ornamentation is reticulate over the posterior third of the shell, the rugae then develop irregularly and the ornamentation of the rest of the shell may be described as costate. The costae radiate from the umbo, those in the central part of the shell converging towards and finally coalescing on the median fold.

The internal features of this species are not shown by any of the Western Australian specimens.

Comparison with other species.—This species is distinct from other Western Australian semireticulate productids in its small size. The convergence of the costae towards the sinus in the pedicle valve and the fold in the brachial valve serve to distinguish it from other small members of the semireticulate group.

In the Western Australian specimens the convergence of the costae is not so marked as in some of the Indian and Timor forms. Examination of the Timor specimens shows, however, that there is a large range of variation in the extent of the convergence.

Remarks.—As the internal features of this species are not known the generic placement is insecure. In external appearance the shells are similar to *Marginifera* Waagen, and knowledge of the internal structures is necessary before it can be said that they do not belong to that genus.

Dictyoclostus spiralis (Waagen).

Pl. ii, figs 8, 9.

1884.—*Productus spiralis* Waagen, p. 681, pl. lxvii, fig. 6; pl. lxviii, fig. 3; pl. lxix, figs. 1, 2, 3.

1916.—*Productus spiralis* Waagen, Broili, p. 11, pl. cxvii, figs. 1-5.

1927.—*Productus spiralis* Waagen, Diener, p. 26.

1928.—*Productus spiralis* Waagen, Hamlet, p. 16.

Material.—Aus. Mus. F 36513, 36514, 36515, Wyndham Gap, North-West Division, Western Australia. Callytharra stage.

Diagnosis.—Shell large, regularly curved through 270°. Hinge-line equal to greatest width. Ears large and reflexed. Pedicle valve highly inflated with arched umbonal region, sides parallel and steep. Ornamentation reticulate on

posterior third of shell, costate on anterior two-thirds, no development of folds on trail. Slight convergence of costae in sinus. Ornamentation on ears partly reticulate, partly costate, costae showing spiral arrangements. Row of spines along hinge-line and along line of separation of ears and flanks.

Brachial valve flatly concave with strong geniculation. Ornamentation reticulate on visceral disc, costate on trail. Ears deeply excavated, smooth or with concentric wrinkles only. No spines. Cardinal process short, trifid. Well developed adductor muscle impressions. Muscle and brachial impressions of typical productid pattern.

Description.—Only pedicle valves are known from Western Australia. These have the following dimensions:—

Description.	1.	2.	3.
Length of hinge-line	88·2	....	63·0+
Height	45·6	58·1	48·9
Curvilinear length	134·0	112·0	99·4

The shell is large, as shown by the table, and curved in a regular spiral, there being no pronounced change in the rate of curvature throughout the period of shell growth. The umbo, though incurved, is blunt and scarcely overhanging the hinge-line. The hinge-line is straight and long, and forms the maximum breadth of the shell, about one quarter of this width being occupied by the ears alone. These are prominent features of the shell, they are strongly reflexed with a triangular outline. Their surface makes an obtuse angle with that of the flanks. A median sinus arises near the umbo and becomes deeper towards the anterior margin.

The ornamentation is reticulate on the posterior third of the shell, the rugae and costae being equally developed, thus giving an even pattern. On the trail the costae become more irregular, this irregularity being due to a change in disposition of the costae above and below the large spines which develop sporadically in this part of the shell. No grouping of the costae into fasciculi is seen in this species. A row of strong spines occurs along the hinge-line and along the flanks at the line of separation of the ears. The ornamentation of the ears is one of the characteristic features of the species. No new costae arise along the hinge-line after the shell ornamentation has ceased to be reticulate and those already formed become more widely separated as the shell grows and, following the curvature of the valve, show a spiral arrangement when viewed from the side.

Comparison with other species.—The spiral ornamentation of the ears is a distinctive character of this species, and differentiates it quite clearly from *Dictyoclostus callytharrensis*. The visceral cavity is much shallower in the latter species, not showing the arching in the umbonal region which is seen both in *D. spiralis* and in *D. callytharrensis* var. *wadei*. In both *D. callytharrensis* and its variation the costae on the trail are grouped into fasciculi, a condition not seen in *D. spiralis*.

For the distinction of *D. spiralis* from the Indian members of the *spiralis-subcostatus* reference should be made to Waagen (1884).

LINOPRODUCTUS Chao.

1927.—Chao, *Palaeont. sinica*, ser. B, V, fasc. 2, p. 128.

1928.—Chao, *ibid*, fasc. 3., p. 63.

1931.—Paeckelmann, pp. 75, 206.

Genotype.—Productus cora d'Orbigny, 1842, Voy. Amér, Mérid., vol. 3, Pal., p. 55, pl. v, figs. 8-10.

Diagnosis.—Thin-shelled Productids with convex pedicle valve; brachial valve flat or concave in visceral portion, sometimes geniculated anteriorly. Hinge-line equal to or less than the greatest width. Both valves without cardinal area. Pedicle valve evenly convex or sinuate.

Surface ornamentation of fine radiating striae and indistinct concentric wrinkles; wrinkles more marked on the brachial valve. Scattered spines on striae present or absent.

Pedicle valve with marginal ridges weak and muscles not strongly impressed. Median septum in brachial valve. No brachial cones.

Remarks.—Chao has divided Linoproductids with wavy undulations and pustulose spines into two groups, one characterised by *P. cancriniformis* (Tschernyschew), and the other by *P. villiersi* d'Orbigny. These groups are separated by the character of the brachial valve, regularly concave in *P. villiersi* and geniculate in *P. cancriniformis.*

Linoproductus cora (d'Orbigny).

1842.—*Productus cora* d'Orbigny, p. 55, pl. v, figs. 8, 10.

1911.—*Productus cora* d'Orbigny, Diener, p. 19, pl. iii, figs. 3-13.

1914.—*Productus cora* d'Orbigny, Kozlowski, p. 48, pl. iv, fig. 19; pl. v, fig. 5; pl. vi, figs. 1-10; text-fig. 8.

1916.—*Productus cora* d'Orbigny, Broili, p. 19, pl. cxv (1), figs. 14-15; pl. cxvi (2), figs. 1-3.

1927.—*Productus cora* d'Orbigny, Chao, p. 132, pl. xiii, figs. 17-18; pl. xiv, figs. 1-4.

1927.—*Productus cora* d'Orbigny, Diener, p. 24.

For complete synonymy see Broili (1916) and Diener (1911).

Diagnosis.—Linoproductids of variable size, transversely oval to elongated oval in shape, hinge-line equal to greatest width of shell.

Pedicle valve swollen, evenly convex in longitudinal profile, medially rounded or with broad sinus; tendency to spread and flatten in fan-like form anteriorly; flanks sloping steeply from visceral portion. Shell arched over hinge-line, umbo incurved, slightly overhanging the hinge-line. Ears flat, their surface perpendicular to flanks of valve. Ornamentation of fine raised and rounded striae, subparallel or flexuous and irregular; increasing in number by intercalation of new striae between those pre-existing. Concentric folds on ears, not crossing visceral disc. Row of spines along hinge margin, spines present or absent on rest of valve.

Description.—Productus cora was first described by d'Orbigny from South America, but the incompleteness of his description led to confusion in the interpretation of the species for many years. The examination of a large number of topotypes by Kozlowski in 1914 showed that there was a large variation within the species, and his description is here summarised. It varied in shape from transversely to longitudinally oval; the pedicle valve might be very swollen in the median region or only moderately so; the umbo was sometimes, but not always, strongly incurved; the pedicle valve was

sometimes impressed by a median sinus, sometimes regularly curved transversely; the striae varied in flexuosity and in the number of spines borne on the body of the valve. Each of these varied independently of the others, except possibly that the flexuosity of the striae was correlated with the presence of spines, one or more uniting, a spine arising at the point of union and the striae then disassociating.

Interiorly the dendritic adductor impressions of the pedicle valve are elongated and parallel to the median line while the diductor impressions are short, broad and longitudinally striated, arising at the lower edge of the adductors. The brachial valve has a raised median septum, adductors dendritic on each side of the septum, reniform impressions running laterally from the base of the adductors, following the lateral and antero-lateral margins, then returning to the point of origin. Cardinal process trilobed, median lobs raised above the two laterals. Marginal ridges arising at the base of the cardinal process and continuing along the hinge to the ears. A hollow separating the ears from the visceral disc, runs obliquely from the base of the cardinal process.

Remarks.—Diener in 1911, after examining a collection of Linoproductid shells from the Fusulina Limestone of Kehsi Mansam suggested that *P. cora* d'Orbigny should be enlarged to include those forms previously assigned to the species *P. neffedievi* Verneuil, *P. corrugatus* McCoy, *P. prattenianus* Norwood and Pratten and *P. lineatus* Waagen. In this collection were forms which, while they could not be separated from the type specimens of these species, formed a continuous series with the specimens of undoubted *P. cora*. Diener's conclusions that *P. cora* included a wide variety of forms has since been strengthened by Kozlowski's work on the topotypes of *P. cora*. Kozlowski regards *P. prattenianus* and *P. lineatus* as members of the *"cora"* species group. He adds, too, *P. ovatus* Hall, but thinks that there is a definite, if unimportant, distinction between *P. cora* and *P. corrugatus* in that in the latter species the spines arise on any striae at its confluence with several others whereas in *P. cora* it is usual for the same stria to bear several spines at different places along its length.

These two authors have each had access to a large number of specimens and have, each independently of the other, found that *P. cora* is a very variable species and includes in itself *P. lineatus, P. prattenianus, P. neffedievi* and *P. ovatus*. The conclusion of such men, working with good material must be accepted, and even while these groups may be distinguished by varietal names, it must be remembered that they all belong to the one species group—*Productus cora* d'Orbigny.

Australian Distribution.—This species has been previously recorded and figured from Tilligharv, N.S.W., by de Koninck. The specimens were, however, burnt in 1882. Other references to this species in Australian literature (Etheridge jun. 1872, Etheridge and Jack 1892, and Etheridge and Dun 1909) are not included in the synonymy of the species as in all the specimens figured the concentric markings are strong on the pedicle valve, a condition not shown in any of Kozlowski's or Diener's figures. These specimens have not been examined, and consequently no opinion is expressed on the validity of the identifications.

Productus cora has been recorded from Western Australia by Chapman and Glauert (1910, p. 87). It was recorded from the Kimberley District by

Chapman in 1924 (p. 36), but the specimen has since been re-examined by Miss Hosking, and re-identified as *Streptorhynchus luiluigui* (Hosking 1932, p. 45).

Linoproductus cora var. **foordi** (Eth. fil).

Pl. iii, figs. 3-5.

1890.—*Productus tenuistriatus* de Verneuil, Foord, p. 151, pl. vii, figs. 4, 4a.

1903.—*P. tenuistriatus* de Verneuil, var. *foordi* Etheridge, jun., p. 19, pl. i, figs. 3-4; pl. iii, fig. 22.

1907.—*P. tenuistriatus* var. *foordi* Etheridge, jun., p. 30, pl. ix, figs. 4-6.

1910.—*P. tenuistriatus* var. *foordi* Eth. fil., Glauert, p. 87.

1931.—*P. tenuistriatus* var. *foordi* Eth. fil., Hosking, pp. 8, 22.

Specimens.—G.S.W.A. 1/4683, south bank of Wooramel River below Callytharra Spring, Callytharra Limestone.

G.S.W.A. 5708b., Fossil Cliff, Irwin River.

Aus. Mus. F 36247, 36251-36255 (incl.), Gascoyne River, near Winnemia. North-West Division. Byro Stage.

Aus. Mus. F 9027, Wyndham River, North-West Division. Byro Stage

Aus. Mus. F 36287, Gascoyne River, North-West Division. Byro Stage.

U.W.A. 10822, Fossil Cliff, Irwin River. Fossil Cliff horizon.

Diagnosis.—Linoproductids with elongate oval outline, hinge-line equal to greatest width of shell.

Pedicle valve without median sinus. Visceral region very swollen, arching over hinge-line, umbo slightly overhanging hinge-line. Ears small and flat. Valve regularly curved in longitudinal profile. Striae fine, irregular, increasing by intercalation along a definite zone. Concentric wrinkles weak, not crossing visceral disc. Groups of spines at cardinal angles and one row at low angle to hinge-line.

Brachial valve concave, ornamentation as in *P. cora* d'Orbigny.

Description.—The pedicle valve has an elongated oval outline in the larger specimens. It is gibbous in the visceral region falling rapidly at the sides to small, flat ears, and truncated posteriorly by a small umbo overhanging the hinge-line. Anteriorly there is a decrease in the curvature so that the shell is elongated rather than globular. A row of spines along the hinge, at about 10° to the cardinal margin terminates in a group of from 4-6 spines on each ear. No spines occur on the rest of the shell. The longitudinal striae are fine (20-40 measured over a breadth of 20 mm. at a distance of 10 mm. from the umbo), and vary in irregularity. On some specimens they may run almost parallel for the length of the shell, but more usually two or more unite and re-divide later, having an irregular course. The striae increase by intercalation and this takes place in most specimens, at about the same stage of growth. The amount of increase, too, varies, one or two striae being intercalated between a pair of primaries. Folds on the ears are not seen on the majority of specimens and where they are present never cross the visceral part of the shell.

The brachial valve is concave, the ornamentation as in the pedicle valve, but crossed by concentric wrinkles. The valve is devoid of spines.

The sizes of the specimens (pedicle valves) are shown by the following table:—

	1.	2.	3.	4.	5.	6.
Height	29·1+	22·8+	31·0+	23·7+	23·0+	14·1
Maximum width	29·4+	25·1+	27·0+	27·0+	24·0+	13·3
Length of hinge-line	22·9+	20·2+	19·8+	25·0	18·6+	13·3
Curvilinear length	50·0+	39·3+	56·0+	41·1+	35·5+	21·8

No specimens examined have both valves in position, it is thus impossible to estimate the thickness of the shell.

The width of the hinge-line as shown by these figures is less than the maximum width of the shell. The ears in these specimens are very fragile and readily break off; the only complete specimen is a small one (No. 6).

The internal structures are as described for the species *P. cora,* the muscles being inserted in definite fossae.

Comparison with other forms.—These specimens have been referred for many years to *Productus tenuistriatus* Verneuil, although distinguished as a variety. Etheridge (1903) separated them as a variety giving as his reasons the much coarser and more irregular ornamentation (in *P. tenuistriatus* there are 50-60 striae in 20 mm. at a distance of 20 mm. from the umbo). They differ from that species, too, in the width of the hinge-line, the arching of the pedicle valve and the regular anterior elongation, *P. tenuistriatus* being irregularly produced anteriorly. Etheridge has already said that this form belonged to the *"cora"* group (1907, p. 30). Specimens from Timor (Broili 1916, pl. cxv., figs. 15-16; pl. cxvi., figs. 1-3) probably belong to this variety of *P. cora.*

This variety is not distinct from *P. cora* d'Orbigny. It is a variety within that species as can be seen by a comparison of Kozlowski's figures (pl. vi., figs. 7a, b) and figures accompanying this paper, but a variety which has become stabilised in this area. The limits of variation are narrower than in those from South America. The shell shape is constant as is the convexity of the pedicle valve, it is not sinuated and does not carry spines on the main part of the shell. The varietal name is retained for these specimens until the complete range of *Productus cora* d'Orbigny is seen in this country.

Linoproductus cancriniformis (Tschernyschew).

1889.—*P. cancriniformis* Tschernyschew, p. 373, pl. vii, figs. 32, 33.

1897.—*P. cancriniformis* Tschern. Diener, vol. 1, Pt. III, p. 25, pl. vi, figs. 6a-b, 7a-d.

1897.—*P. cancriniformis* Tschern. Diener, vol. 1, Pt. IV, p. 31, pl. 1, figs. 7-10.

1907.—*"P. undatus"* Defrance, Eth. fil., p. 30.

1916.—P. *cancriniformis* Tschern., Broili, p. 13, pl. cxvi, fig. 6.

1918.—*"P. bellus"* Eth. fil., p. 254, pl. xxxix, fig. 4-5; pl. xl, fig. 6.

1928.—*L. cancriniformis* (Tschern.), Chao, p. 65, pl. v, figs. 8-9.

1934.—*L. cancriniformis* (Tschern.), Prendergast, p. 14, pl. ii, figs. 7-12.

1936.—*L. cancriniformis* (Tschern.), Douglas, p. 30, pl. iv, fig. 3.

Material.—Aus. Mus. F 38453-38457, 9069, Minilya River, North-West Division. Wandagee Stage.

Aus. Mus. F 37580, ¼ mile west of shale outcrop. Northern bank. Same locality and horizon.

Aus. Mus. F 37576, ¾ mile east of shale outcrop. Northern bank. Same locality and horizon.

Aus. Mus. F 16729, 10749, Irwin River District Fossil Cliff horizon.

Aus. Mus. F 37565, ¼ mile east of fault, south bank of Minilya River, North-West Division. Wandagee Stage.

Diagnosis.—Linoproductids with non-sinuate pedicle valve, hinge-line equal to greatest width of shell, umbo overhanging hinge-line; ears distinct but not prominent. Shell ornamentation of fine striae, becoming swollen at regular intervals to give anteriorly-directed spines, quincuncially arranged. Row of spines along cardinal margin. Visceral disc crossed by concentric wrinkles; size and extent of wrinkles variable.

Brachial valve flat over visceral disc becoming strongly geniculated anteriorly. Short median septum. Ornamentation as on pedicle valve.

Internal features not known.

Description.—For description and discussion of this species see Prendergast, 1934, p. 14.

Linoproductus cancriniformis var. **lyoni** var. nov.

Pl. iii, figs. 1-2.

Holotype.—Aus. Mus. F 36530, 10 chns. north-west of Gnarrea Pool near Winning Statin, North-West Division. Lyons Stage.

Topotypes.—Aus. Mus. F 36533, 36535, 36537, 36538, 36540. Same locality and horizon.

Diagnosis.—Shell medium to large, semi-circular outline. Pedicle valve evenly convex, not swollen, without median sinus. Hinge-line straight, equals greatest width of shell. Umbo strong, not incurved, not overhanging hinge-line. Ears large, flat, not clearly differentiated from body of shell. Ornamentation as in *Linoproductus cancriniformis* Tschern.

Brachial valve and internal structures of pedicle valve not known.

Description.	Dimensions.		
	36530.	36531.	36532.
Length of hinge-line	43·7	34·5	22·7
Height	32·6	28·0	21·5
Curvilinear length of pedicle valve	41·0	25·8	34·2

The pedicle valve has a semi-circular outline with the greatest width at the hinge-line. The longitudinal profile of the shell is a regular curve becoming geniculate near the front; transversely the curve is regular, without any median flattening. The ears are large with alar angles right angles, they are not distinct from the body of the shell. The shell surface is covered with fine radial striae (10-13 in 10 mm. measured at a distance of 20 mm. from the umbo) bearing swollen elongated spine-bases arranged in

quineunx. The striae increase in number by division of primaries. Concentric wrinkles are present on the ears but these rarely extend onto the body of the shell. A row of large erect spines is found along the cardinal margin.

Comparison with other species.—Only pedicle valves are known of this variety. These, however, are such a distinctive shape that it has been thought best to distinguish them temporarily as a variety of *Linoproductus cancriniformis* (Tschern.). The ornamentation of the variety is similar to that of Tschernschew's species with the same fine radial striae and elongated pustules. They differ in the much less convex pedicle valve and in the semicircular outline with the greatest width at the hinge-line.

The variety shows also a marked resemblance to *Productus asperulus* Waagen (1884 p. 693 pl. lxxix. figs. 3-6) in outline and type of ornamentation. The spines in that species are erect and not elongated pustules seen in *Linoproductus cancriniformis.*

Productus koninckianus de Vern. (Chao 1928, p. 63 pl. v. figs. 4-7) has also some features in common with these shells. It has, however, a much more inflated pedicle valve though several figures of smaller specimens (Chao 1928, pl. v. fig. 6) have a flat pedicle valve. The Western Australian specimens are always larger than these smaller shells and never have an inflated and incurved umbo. *Productus tumidus* Waagen (1884, p. 708, pl. lxxx. figs. 1-3) is also an inflated form and bears erect spines.

WAAGENOCONCHA Chao.

1927.—Chao, Y. T. *Palaeont. sinica*, Ser. B., V, fasc. 2, p. 85.

Diagnosis.—Thin-shelled productids with convex sinuate pedicle valve, brachial valve flat or concave. Surface marked by quincuncially arranged tubercular spines in the young and adult stages, becoming smaller and more closely packed together in old age.

Genotype.—Productus humboldti d'Orbigny, 1842, Voy. Amér. Mérid., Vol. 3, Pt. 4, p. 54, figs. 4-7.

Waagenoconcha imperfecta Prendergast.

Pl. iii, figs. 7-9.

1924.—*"Productus subquadratus"* Morris, Chapman, p. 36.

1934.—*Waagenoconcha imperfecta* Prendergast, p. 15, pl. iv, figs. 1-3.

Holotype.—U.W.A. 3044, Luiluigui Station, Kimberley Division. Liverynga Series.

Allotypes.—U.W.A. 2768, 2775, same locality and horizon.

Topotypes.—U.W.A. A 444, Luiluigui Homestead, Kimberley Division, Liverynga Series.

Other Material.—U.W.A. 20457, Limestone at base of Mt. Hardman, Kimberley Division. Liverynga Series.

U.W.A. 20454, north flank of Mt. Cedric, Kimberley Division. Liverynga Series.

Diagnosis.—Shell transversely oval in outline, hinge-line less than greatest width of shell. Ornamentation on both valves of coarsely spaced quincuncially arranged spine bases with fine forward projecting spines. Shell with well marked growth lines.

Pedicle valve evenly convex, sinuate, umbo prominent, produced beyond hinge-line.

Brachial valve flat to slightly concave with a shallow median fold. Margins not geniculate.

Description.—See Prendergast 1934, p. 15.

Remarks.—In the earlier specimens of this species examined it was noted that the specimens did not agree with the generic description since the spines were less crowded anteriorly. Specimens in a better state of preservation have since been obtained and these show that the inclusion of the species in the genus *Waagenoconcha* is quite justified. In these specimens the spines are crowded together on concentric wrinkles on the older parts of the shell. The absence of this feature on the earlier specimens was undoubtedly due to exfoliation of the outer layers of the shell leaving only coarser pustules more widely spaced.

When this species was originally described no copy of Broili's (1916) work on the Permian Brachiopoda of Timor was available and a new species was founded to contain specimens which belong to *Productus waageni* Rothpletz as figured by Broili. Comparison of the Western Australian specimens with Broili's figured specimens and with others from Timor (Basleo, Neoetpantoekak, Toenion Eno, Timor. B.M. B. 98397, 98985, 98648) leaves no doubt on this point. The Western Australian name is retained because it is doubtful if *P. waageni* Broili is identical with *P. waageni* Rothpletz.

Rothpletz's figures of *P. waageni* (1892, pl. x. fig. 19) show a small shell transversely oval in outline, ornamented with fine closely set spine bases. It shows no growth lines and has a very weak sinus in the pedicle valve. But Rothpletz compares his specimens with *P. humboldti* as figured by Waagen (1884, pl. lxxvi. figs 1-3), a rather surprising comparison as most of the specimens figured by Waagen have well-marked concentric ornamentation. Indeed Rothpletz's figures (pl. x. fig. 20) of *P. abichi* are more like *P. humboldti* Waagen. If *P. waageni* Rothpletz is identical with *P. waageni* Broili, then the absence of growth lines on Rothpletz's type is due to weathering or to individual variation. Without inspection of the type specimen of *P. waageni* Rothpletz, this species must be regarded as without growth lines.

Waagenoconcha vagans Reed.

Pl. iii, fig. 6.

1931.—*Waagenoconcha vagans* Reed, p. 9, pl. ii, fig. 2.

Material.—One brachial valve, U.W.A. 20459, north flank of Mt. Cedric, Kimberley Division. Liveryuga Series.

Diagnosis.—Shell trapezoidal to almost square in outline, hinge-line less than the greatest width of shell.

Pedicle valve sinuate, umbo swollen and overhanging hinge-line, ears flat. Ornamentation of small spine bases quincuncially arranged, pits occurring between spine bases.

Brachial valve flat with shallow median folds, margins geniculated.

Description.—This species is known in Western Australia only as an external cast of a brachial valve.

The shell is trapezoidal in outline, the greatest width at the anterior margin, this and the hinge-line being the parallel sides. The hinge-line is short and equal in length to half the maximum width of the shell. The flat visceral disc is divided medially by a shallow fold, the fold widening anteriorly. Laterally and anteriorly the margins of the valve are geniculated to form a fringe. The surface of the shell is ornamented by numerous hollows and spine bases quincuncially arranged (18 spine bases in 10 mm. 20 mm. from umbo), resembling the ornamentation of *W. imperfecta* mihi. Numerous growth lines cross the surface of the valve.

From its impression the umbo of the pedicle valve seem to be swollen and overhanging the hinge-line.

The brachial valve has a length of 29 mm., with a maximum width of 38 mm.; the length of the hinge-line is 24 mm.

Remarks.—This species was first described by Reed from the middle Productus Limestone at Kumaranwali in the Warcha Valley of the Western Salt Range. It is characterised by the ornamentation in conjunction with the geniculation of the brachial valve.

TAENIOTHAERUS Whitehouse.

1928.—Whitehouse, *Rep. Aust. Ass. Adv. Sci.*, vol. xviii, pp. 281, 282.

Genotype.—Productus subquadratus Morris, 1845, in Strzelecki, Physical description of N.S.W. and Van Diemen's Land, p. 284.

Diagnosis.—Adult shell large, general outline subquadrate to elongate oval; pedicle valve evenly convex with median sinus; brachial valve slightly convex to flat with upturned margins. Pedicle valve sometimes with triangular concave area; delthyrium, where present, partially filled by triangular extension of cardinal margin of brachial valve.

Ornamentation of coarse elongated spine bases possibly giving rise to long spines; spine bases not continuous into costae. Irregular concentric wrinkles or lamellae widely spaced over whole shell.

Muscle impressions as in *Aulosteges* and *Productus*. Brachial valve with median septum. Cardinal process large, varying angle of inclination to cardinal margin.

Remarks.—For description of this genus *see* Prendergast, *Proc. Roy. Soc. Tasmania.**

Taeniothaerus subquadratus (Morris).

Pl. iv, figs. 1-6.

1845.—*Productus subquadratus* Morris in Strzelecki, p. 284.

1892.—*Productus subquadratus* Morris, Etheridge and Jack, p. 282, pl. xxxviii, figs. 7-10; pl. xl, fig. 5.

1907.—*P. subquadratus* Morris, Etheridge, jun., p. 21, pl. iii, figs. 6 and 7 (in the plate fig. 7 is labelled as fig. 1).

1907.—*P. subquadratus* Morris (?), Etheridge, jun., p. 30, pl. vii, figs. 2, 4; pl. viii, fig. 1.

1909.—*P. subquadratus* Morris, Etheridge and Dun, p. 300, pl. xli, figs. 1-5.

1910.—*P. subquadratus* Morris, Glauert, p. 87.

1914.—*Aulosteges baraeoodensis* Eth. fil., Etheridge, jun., p. 33, pl. iv, figs. 11-13.

1931.—*P. subquadratus* Morris, Hosking, pp. 8, 22.

1933.—*P. subquadratus* Morris, Hosking, p. 36.

1933.—*Aulosteges cf. A. spinosus* Hosking, p. 36.

1935.—*P. subquadratus* Morris, Prendergast, p. 17, pl. iv, fig. 4.

Holotype.—B.M. 91171, Mt. Wellington and Mt. Dromedary, Tasmania.

Other Material.—U.W.A. 4768, 12396, 20450, 21247, Fossil Cliff, Irwin River, Fossil Cliff horizon.

U.W.A. 10931, two miles north of Ballythanna Hill, Wooramel River District. Byro Sandstone.

U.W.A. 20447, below Coolkilya Pool, Minilya River, North-West Division. Wandagee series.

G.S.W.A. 10930, Mt. Marmion Kimberley Division. Exact horizon not known.

G.S.W.A. 10929, locality and horizon not known.

G.S.W.A. 1/4655, locality and horizon not known.

* In January, 1941, Dr. Prendergast had completed a paper for the Royal Society of Tasmania on this subject, and was awaiting the illustrations, but the paper has not yet appeared.—E. deC. Clarke, 22/3/43.

Diagnosis.—Shell large, subquadrate to oval in outline. Greatest width near anterior margin. Pedicle valve strongly and evenly convex with median sinus, with or without cardinal area. Brachial valve slightly convex to concave with upturned margins.

Ornamentation essentially spinose. Spine bases elongated posteriorly. Concentric lamellae or wrinkles crossing shell surface.

Internal features as in *Productus* s.l. Cardinal process vertical to inclined almost to horizontality. Median septum in brachial valve.

Description.—This species has been described and discussed in Prendergast (*Proc. Roy. Soc. Tas.*)*, but some special features of the Western Australian shells are added here.

The pedicle valve is strongly convex with steep flanks and indented by a median sinus, which flattens out anteriorly so that the margin may be entire. The area is narrow in some specimens but may become wide. It is divided by a definite delthyrium which is partially filled by a triangular projection of the brachial valve. The adductor impressions are dendritic and placed high in the valve, the longitudinally striated diductors arise at the sides of the adductors and are produced laterally and anteriorly.

The brachial valve is flattish with a slightly convex region near the umbo; it is upturned at the margins. The cardinal process is strong and trilobed and varies in its inclination to the plane of the valve from being coplanar to almost perpendicular, the process in this case assuming a horizontal position. The median septum arises at the base of cardinal process and continues forward for about two-thirds of the length of the valve. The adductor muscle impressions are dendritic and enclosed in a heart-shaped elevation whose apex is at the base of the cardinal process. From the base of this elevation arise the brachial impressions, these running parallel to the hinge-line

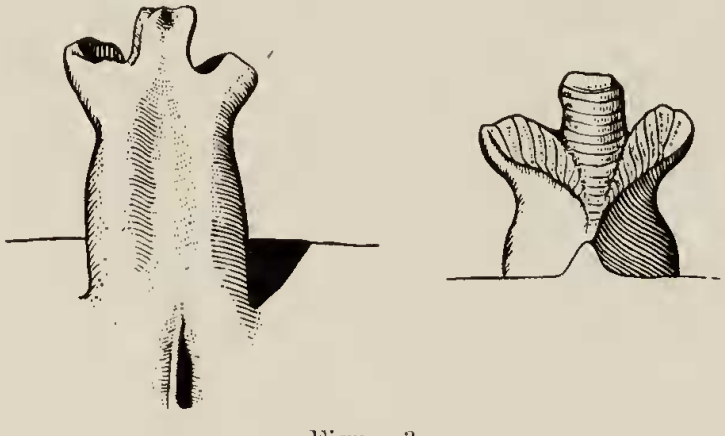

Figure 3.
Cardinal process of **Taeniothaerus subquadratus** (Morris). ×3.

almost to the lateral borders then turning in a circular path and returning to their points of origin parallel to their outward path. At the base of the cardinal process arise two laterally directed ridges running parallel to the hinge-line but dying out before reaching the ears.

The ornamentation of the shell varies within rather wide limits. It is essentially spinose but the intensity of the spinosity varies from locality to locality. In the Irwin shells and those from the North-West Division the spines are very fine and closely set on concentric lamellae, in those from the Kimberley Division they are much thicker and fewer in number.

* See footnote p. 27.

Remarks.—From the Fossil Cliff Beds, Irwin River, are found shells which possess an elongated narrow area. Those specimens from the Byro sandstone of the Wooramel River have a distinct though not large area, while a specimen from the Kennedy sandstone (North-West Division) has been identified as *Aulosteges ingens* Hosking, although it differs from the Byro specimens only in the greater development of the area and the horizontality of the cardinal process. The stratigraphical relationships of these beds are given by Raggatt (1936) and Rudd and Dee (1932, MSS. unpublished).

N.W. Division and Wooramel River.		Irwin River.
Gascoyne Series		
5. Wandagee		
4. Kennedy		
3. Byro		
2. Wooramel		
1. Callytharra	=	Fossil Cliff Beds.

The specimens of these species may, then, be arranged in a time series, in which the area increases in size as the fossil-bearing rock is younger in age. The cardinal process also changes gradually through this series. In the typical *Productus* (e.g. *Dictyoclostus semireticulatus* (Martin)) the cardinal process is erect and in specimens with small areas this statement also holds for *Taeniothaerus subquadratus* (Morris). In *Aulosteges baracoodensis* Eth. fil., however, as in all *Aulosteges* the cardinal process has become bent through a right angle. This change, from vertical to horizontal, takes place gradually and keeps pace with the growth of the cardinal area. The suggestion is therefore made that *Taeniothaerus subquadratus* (Morris) is a transitional form connecting an unknown *Productus* with *Aulosteges baracoodensis* Eth. fil.

KROTOVIA Fredericks.

1928.—Fredericks, G., *Bull. Com. Geol. St. Petersb.*, 46, 1927, p. 790.

Genotype.—*P. spindulosus* J. Sowerby, 1814, Min. Conch., Vol. 1, pl. lxviii, fig. 3.

Diagnosis.—Small thin-shelled producti. Pedicle valve convex, brachial valve concave to geniculate, closely following curve of pedicle valve. Ornamentation of fine spines in irregular quincuncial arrangement covering whole shell surface; spine bases elongated in anterior part of shell. With or without weak concentric wrinkles, median sinus only slightly developed or absent.

Internal structures unknown.

Comparison with other genera.—This genus differs from *Pustula* Thomas in the absence of marked concentric wrinkles and in the nature of the visceral cavity. In *Pustula* the brachial valve is flattish, forming a large visceral cavity, whereas in *Krotovia* the brachial valve follows the pedicle valve so closely that the visceral cavity is thin. Schuchert and Le Vene consider that this is not sufficient distinction as they say (1929, p. 72) of *Krotovia* "appears to equal *Pustula* Thomas." The shape of the body cavity is, however, a feature of diagnostic importance, and I have, therefore, adopted Frederick's genus.

Frederick's diagnosis of *Krotovia* (p. 790) states: "The shell has an oval configuration and a plain surface. The ornamentation consists of spines only," and in the Russian text (p. 779) "Sometimes irregular ribs and folds

develop which are connected with the spines." *Krotovia* then includes specimens with incipient plications thus overlapping with *Avonia* Thomas. Paeckelmann (1931, p. 77) has emphasised this fact, and distinguished *Avonia* s.str. and *Krotovia* as subgenera of *Avonia* Thomas, the forms to be separated by the presence (*Avonia*) or absence (*Krotovia*) of costae. The distinction is thus purely arbitrary, the two genera intergrading.

Krotovia senticosa (Hosking).

1932.—*Pustula senticosa* Hosking, p. 47, pl. iii, figs. 2-3.

Syntypes.—G.S.W.A. 1/4970 (a), from Creek ½ mile west of Callytharra Springs, Wooramel River. Callytharra Limestone

Diagnosis.—Thin-shelled form, outline semi-circular to subquadrate, hinge-line less than maximum breadth. Pedicle valve gently convex, non-sinuate, auriculate, umbo pointed and incurved. Brachial valve strongly concave; visceral cavity of *Productus typici* β type. Ornamentation on both valves of erect spines in irregular quincunx and fine concentric lamellae.

Internal features of pedicle valve unknown, brachial valve with short, broad cardinal process continuing into short median septum.

Description.—See Hosking, 1932, pp. 47-49.

Remarks.—The type specimens of this species have a convex pedicle valve with a concave brachial valve, the visceral cavity between the two being very thin. Also, as Miss Hosking says in her description (p. 48) "the lack of any marked concentric ornamentation is one of the chief features of the species." The specimens must, then, be referred to *Krotovia* rather than to *Pustula*.

Krotovia micracantha (Hosking).

1932.—*Pustula micracantha* Hosking, p. 49, pl. iv, figs. 4a, b.

Syntypes.—G.S.W.A. 1/4970 (b), from Creek ½ mile west of Callytharra Spring, Wooramel River. Callytharra Limestone.

Diagnosis.—Small, thin-shelled form. Shell outline semi-circular to subquadrate, hinge-line slightly less than greatest shell breadth. Pedicle valve geniculate, non-sinuate; umbo small, not overhanging hinge-line. Brachial valve deeply concave and geniculate, closely following contour of pedicle valve; visceral cavity of *Productus typici* β type. Ornamentation on pedicle valve of recumbent spines in irregular quincunx with concentric folds posteriorly and on ears.

Short median septum in brachial valve. Other internal features not known.

Description.—See Hosking, 1932, pp. 49-50.

Remarks.—From an examination of the type specimens there can be no doubt that this species should be referred to *Krotovia*. The visceral cavity is thin, the concentric wrinkles are not pronounced and the nearest British form is *P.spinulosus* J. Sow., the genotype of *Krotovia*.

Krotovia spinulosa (J. Sowerby).

Pl. iv, figs. 11-13.

1814.—*Productus spinulosus* J. Sowerby, p. 155, pl. lxviii, fig. 3.

1860.—*Productus spinulosus* J. Sowerby, Davidson, p. 182, pl. ii, figs. 23, 24.

1861.—*Productus spinulosus* J. Sowerby, Davidson, vol. ii, part 5, No. 4, p. 175, pl. xxxiv, figs. 18-21.

1914.—*Pustula spinulosa* J. Sowerby, Thomas, p. 314, pl. xviii, figs. 7-9; pl. xix, figs. 7, 8.

1930.—*Krotovia spinulosa* (Martin), Muir-Wood, p. 106. (There is no *Productus spinulosus* Martin—this is a mistake in author of species).

Holotype.—Present location unknown, listed as Royal Scottish Museum, Edinburgh, Fleming Collection. Carboniferous Limestone, West Lothian, Linlithgowshire.

Material.—Aus. Mus. F 38442, 38443, 38446, Wandagee Station, Minilya River, North-West Division. Wandagee Stage.

Aus. Mus. F 37563, 37564, 37578, 37582, bank of Minilya River, North-West Division. Wandagee Stage.

Aus. Mus. F 37725.

Aus. Mus. F 37579, ¼ m. west of shale outcrop, northern bank of Minilya River, North-West Division. Wandagee Stage.

Diagnosis.—Shell small. Outline oval, hinge-line less than maximum width. Pedicle valve convex, non-sinuate, umbo small, pointed and incurved. overhanging hinge-line; ears small and flat. Brachial valve evenly concave. Visceral cavity of *Productus typici* β type. Ornamentation on both valves of fine oblique spines, closely spaced, with quincuncial arrangement. Development of incipient costae below spines near anterior margin.

Internal features not known.

	Dimensions.		
Description.	Type.	F 38443	F 38446
Height		16.2	16.5
Length of hinge line		10.5+	12.5
Maximum width		11.7+	17.3
Curvilinear length of pedicle valve		29.4	27.4

The shells of this species, as may be seen from the table, are small. Usually transversely oval, they have a straight hinge-line shorter in length than the maximum width of the shell.

The pedicle valve is evenly convex, without a median sinus. The shell has its maximum convexity behind the umbo; from this point the sides drop steeply to flat ears; anteriorly the slope is more gradual. The alar angles are obtuse. The umbo is small, pointed and overhanging the hinge-line. The surface of the valve is ornamented by small closely-set spine bases (10-12 in 10 mm. at a distance of 10 mm. from the umbo). These give rise to slender oblique spines on the body of the shell; they have not been observed on the ears, but a row of erect spines separates the ears from the body of the shell. On the anterior and lateral slopes small ripples (? incipient plications) are seen anterior to the spine bases.

The brachial valve is regularly concave with the maximum concavity just beneath the umbo. The ears are flat and in contact with those of the pedicle valve. The ornamentation is the same as that seen on the pedicle valve, but no spines are preserved on the brachial valves. A few growth lines cross the shell.

Comparison with other species.—*Productus opuntia* Waagen resembles this species in many particulars. Both have the same outline, but may be distinguished by the location of the maximum width which in *P. opuntia* is the length of the hinge-line. The spine bases of *P. opuntia* are not so crowded as those of *P. spinulosus* and generally are more robust, having a distinct anterior prolongation and are also more nodular.

Girty (1908, p. 264) compares his species *Productus signatus* with *P. opuntia*. The figures are not clear, but give an impression of an ornamentation of *Cancrinella* rather than of *Krotovia* or *Pustula*. The spine bases are heavy and elongated, and Girty himself says that on some of the casts irregular lirae can be seen between the spine bases. The species is distinct from *K. spinulosa*.

The characters distinguishing the other species of this genus, *Krotovia micracantha* and *Krotovia senticosa*, from this species are dealt with in the description of those species.

AULOSTEGES Helmersen.

1847.—Helmersen. Leonhard & Bronn's Jahrbuch für Mineralogie p. 331, text-figure.

Genotype.—Aulosteges variabilis Helmersen = *Orthis wangenheimi* (Verneuil). Helmersen 1847, Leonhard and Bronn's Jahrbuch für Mineralogie, p. 331, with text-figure.

Diagnosis.—Medium to large shells, ovoid to quadrangular or triangular in outline. Concavo-convex or platy-convex dorso-ventrally. Ornamentation essentially spinose with development of radial lirae or concentric wrinkles.

Pedicle valve convex with well-developed area and pseudo-deltidium. Umbo pointed, possibly deformed or with cicatrix of attachment. Edentulous. Shell with median sinus.

Brachial valve flat or concave, without area or area narrow and linear. Cardinal margin produced into triangular extension medially. Median septum separating dendritic muscle impressions. Pattern of brachial impressions productiform. Cardinal process large, inclined or horizontal.

Description.—The shells of this genus are usually massive although there is a great variation within the genus. They vary in shape from oval to quadrangular and triangular, the hinge-line being less than the greatest width of the shell. Neither the pedicle nor the brachial valve is produced into distinct ears.

The pedicle valve is regularly convex or geniculate. Transversely it is depressed by a median sinus which commences some distance behind the umbo, is strongest in the centre of the shell and flattens out towards the anterior margin. The area is triangular and usually well-developed, it is marked by vertical or longitudinal striations and may be flat or concave; the concavity may not be regular and a sudden change in curvature gives the recurved area seen in *A. spinosus*, Hosking. A narrow pseudo-deltidium, triangular or parallel-sided, divides the area. In some specimens, for instance *Aulosteges wangenheimi* (Verneuil), small spines are present on the pseudo-deltidium. These are not seen in all other species, but their occasional occurrence suggests that their absence is secondary, due to removal. The umbo is sharp and pointed, and usually erect. Where, however, the umbo has been deformed by attachment, it may be twisted to one side or produced across the area (*see*, for example, *Aulosteges baracoodensis* Eth. fil., 1914, pl. iv, fig. 13). The surface of the valve is ornamented by spines, erect and/or adherent, and may be concentrically wrinkled on the visceral disc. Radial lirae are seen in some of the species, e.g., *A. wolfcampensis* King and *A. medlicottianus* Waagen, while stronger radial markings ornament the trail in *A. tibeticus* Diener.

The brachial valve of the genotype *A. wangenheimi* (Verneuil) is slightly convex over the visceral disc, becoming concave with geniculated margins. This valve has an operculiform character throughout this genus, serving as a flattish or slightly concave lid for the visceral cavity. The ornamentation is as in the pedicle valve.

A description of the internal features of a brachial valve of *A. wangenheimi* (B.M. BB 3279) will illustrate the characteristic features of the valve.

The cardinal process is large and trilobate, it is inserted perpendicular to the hinge-line so that it extends horizontally, not vertically as in the *Productids*. The roots of the cardinal process extend posteriorly, and some part of them now lies behind the hinge-line. This is protected externally by a triangular extension of the brachial valve which fills the delthyrium of the pedicle valve. This structure of the cardinal process is characteristic of the genus.

At its base the cardinal process is continued into two thickened ridges which run parallel to the hinge-line, leaving, posterior to them, a rectangular platform of which the surface of the valve forms the back and the thickened ridge the floor. The development of these ridges varies within the one species even under the same environmental conditions; one of the specimens examined (B.M. BB 3278) had them enormously thickened (see Figure 4), while in another they were but feebly developed with little laterial expansion. In the thickened specimen two ridges, directed towards the centre of the shell, arise at the base of the cardinal process and unite in the middle line to continue forward as the median septum. These two ridges and the lobes of the cardinal process form the edges of a diamond-shaped depression which separates the cardinal process from the median septum. With less-developed ridges the anterior sides of the depression become obscured.

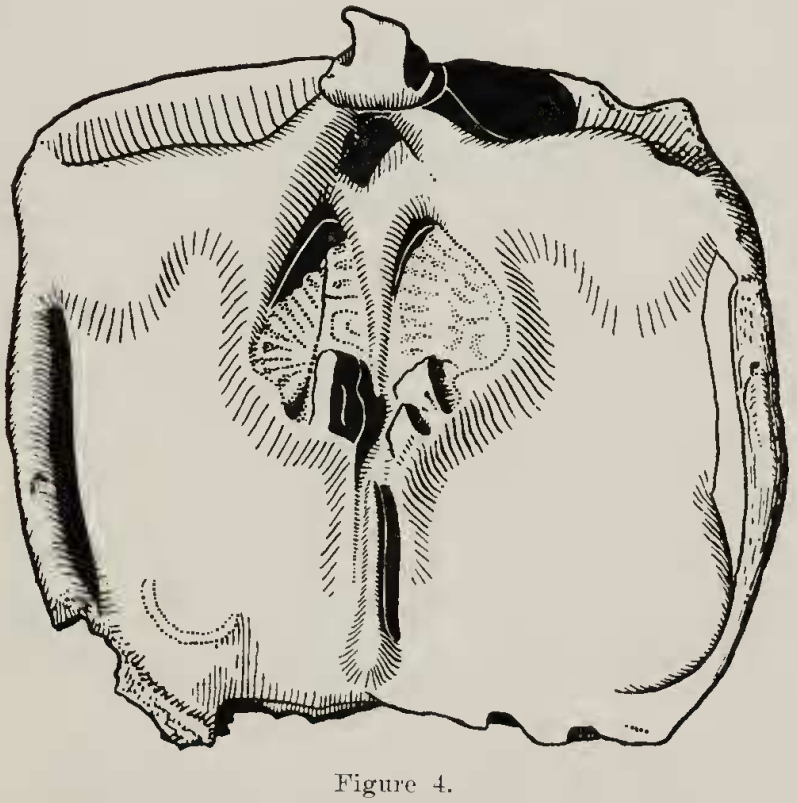

Figure 4.
Interior of Brachial Valve of **Aulosteges wangenheimi** (Verneuil). Permian. Mt. Grebeni, near Orenburg, Russia. B.M. BB 3279 (×3).

The dendritic muscle impressions are situated in sub-triangular depressions on each side of the median septum. At the base of each, the brachial impression arises, runs parallel to the hinge-line almost to the lateral margin, then turns anteriorly to form an open loop. On no specimen have the impressions continued to the median septum. In the area circumscribed by the brachial impressions the inner shell surface is smooth and shiny, elsewhere it is finely pitted.

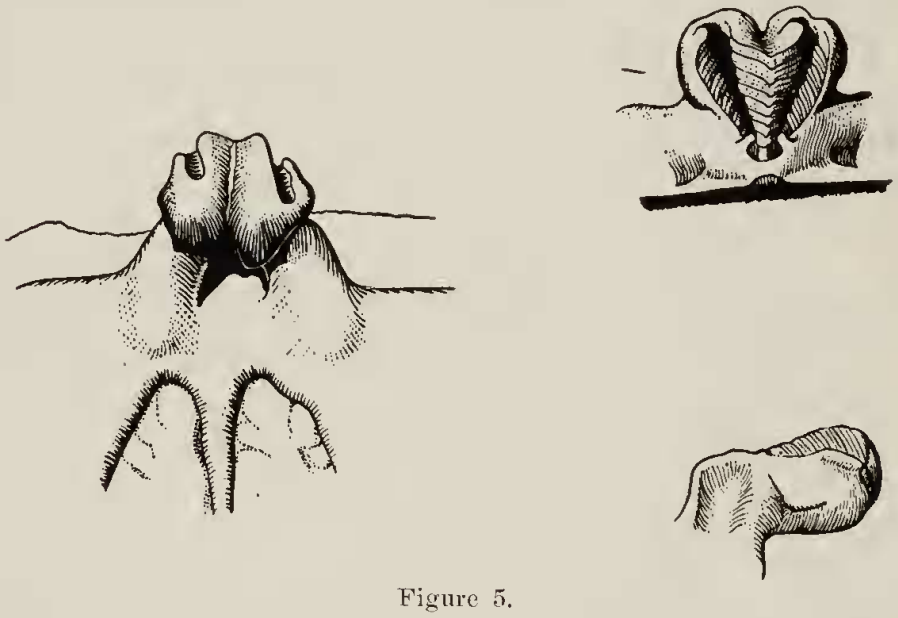

Figure 5.

Cardinal Process of **Aulosteges wangenheimi** (Verneuil). Permian. Mt. Grebeni, near Orenburg, Russia. B.M. BB 3278. (a) vertical, (b) lateral (c) horizontal (×3).

Comparison with other genera.—The genus *Aulosteges* is distinct from members of the Strophalosiinae in the possession of a high reclined area, poor articulation, a cardinal process orientated perpendicular to the commissural plane of the valves, the triangular extension of the cardinal margin of the brachial valve and the dendritic adductor impressions in the brachial valve.

The high area of *Aulosteges* and the horizontal inclination of the cardinal process serve as distinguishing features from the *Productus spinosi* group.

In view of the prevailing opinion of Russian palaeontologists that *Aulosteges* is a synonym of *Strophalosia,* the differences between the two genera will be considered more fully. Netschajew (1911, p. 144) states that the only significant feature distinguishing the two is the presence of deltidial spines in *Aulosteges.* Such a statement completely ignores the differences in the internal structure of the brachial valve. It must be admitted, however, that the internal features of the Russian species *Strophalosia horrescens, S. fragilis* and *S. gigas* are very similar to those of *Aulosteges.* The muscle impressions are dendritic, the cardinal process inclined towards the horizontal and the pattern of the brachial impressions productoid. It is here that the error lies, for those species mentioned above do not belong to the genus *Strophalosia,* they are *Aulosteges.*

Licharew (1937, p. 128), while stressing the synonymity of *Aulosteges* and *Strophalosia*, recognised that the Russian "*Strophalosia*" did not come within the accepted conception of that genus. He compromised by suggesting

that the *S. horrescens* group should be distinguished as *Aulosteges,* a sub-genus of *Strophalosia.* But why a sub-genus? *Strophalosia* is distinguished by non-dendritic muscle impressions, a smallish cardinal process, a reclined area of moderate height in the pedicle valve and well-developed dentition. What features, therefore, have *Aulosteges* and *Strophalosia* in common that would induce us to consider one as a sub-division of the other? The possession of a concavo-convex shell with an area on the pedicle valve and usually a spinose ornamentation is surely insufficient evidence for this grouping when so many points of difference are considered.

Fredericks has a more positive reason for distinguishing between the two genera. He says (1931, p. 209) that both genera are characterised by the presence of an apical apparatus representing a reduced spondylium. The apical plates have become delthyrial ridges and the secondary septum a median ridge. These elements, Fredericks says, retain their connection at the apex of the umbo. He publishes no diagrams in support of this hypothesis, which rests, therefore, solely on his interpretation of these structures—structures which would be preserved in only those specimens where no deformation of the umbo had occurred. The presence of such a structure would not do more than suggest a similar origin for both genera, a view which has not been disputed, and if other points of difference are present, would not preclude the maintenance of each as a separate genus.

Subgenera.—Two subgenera of *Aulosteges* have been proposed:

Wyatkina Fredericks.

Strophalosiina Licharew.

These subgenera agree with *Aulosteges* in essentials, but differ in minor details.

Wyatkina Fredericks (1931, p. 210 footnote) with subgenoholotype *Aulosteges gigas* Netschajew includes:—

> "*Stropralosia*-like forms, yet with primitive apical apparatus devoid of delthyrial ridges and euseptoid. Ornamentation consisting of thin spines. Muscle impressions of the ventral valve and structure of the dorsal valve as in *Strophalosia.*" (The *Strophalosia* of this paragraph refers to the Russian forms, i.e., *Aulosteges.*)

Licharew suggests (1937, p. 128) that the delthyrial ridges are probably only present when the deposition of shell substance has been excessive and these ridges would be the outward manifestation of teeth. This explanation seems quite plausible. As few *Aulosteges* possess either teeth or delthyrial ridges, Fredericks's subgenus would include nearly all the members of the genus. Further observations are necessary before any conclusion can be accepted with certainty.

Strophalosiina Licharew (1935, p. 369) with subgenoholotype *Aulosteges tibeticus* Diener is distinguished from other members of *Aulosteges* by its geniculate pedicle valve and peculiar ornamentation. Anterior to the geniculation the surface of the shell is covered with radial plications while on the visceral disc the plications are replaced by irregular concentric wrinkles and radially arranged pustules.

These subgenera, *Wyatkina* and *Strophalosiina* are closely related. Indeed, from a study of the literature they seem identical, since according to Hamlet, *A. tibeticus* = *A. medlicottianus,* while Renz says that *A. gigas* =

A. medlicottianus; therefore, since those things which are equal to the same thing are equal to one another:—

A. tibeticus = *A. gigas*,
therefore *Wyatkina* = *Strophalosiina*.

If the premises are true *Strophalosiina* is a synonym of *Wyatkina*. The author has not been able to see the original description and figures of *A. gigas*, so cannot discuss its affinities with *A. tibeticus*. The diagnostic feature of *A. tibeticus* is the ornamentation, and later writers on *A. gigas* do not describe that shell as radially plicate.

Until further information is available, *Strophalosiina* and *Wyatkina* are accepted as subgenera of *Aulosteges*.

Aulosteges spinosus Hosking.

Pl. iv, figs. 7-10.

1931.—*Aulosteges spinosus* Hosking, p. 17, pl. iii., figs. 7a-d.

1933.—*Aulosteges spinosus* Hosking, p. 37.

Material.—Aus. Mus. F 38444, 37710, Wandagee Station, Minilya River, North-West Division. Wandagee Stage.

Diagnosis.—Shell small to medium in size, subquadrangular, wider than long. Surface of both valves with small perforated tubercles bearing small spines.

Pedicle valve convex, not swollen, faint median sinus. Umbo high, not overturned, Area broad, slightly concave and recurved to cardinal margin, pseudo-deltidium narrow, highly arched.

Brachial valve flat, triangular extension of cardinal margin large.

Internal features unknown.

Description.—For complete description of this species reference should be made to Hosking (1931, p. 17 et seq.).

Two rather dissimilar species from the North-West Division are here referred to this species.

Dimensions.

	Type :	38444.	37710.
Length	18·8	45·1 +	20
Breadth	19·7 +	43·0 +	22
Length of hinge-line	14·5	21·3 +	15
Thickness	—	7·4	—

F 38444 is a complete specimen with both valves. The umbo is distorted by a cicatrix of attachment and twisted slightly to the left. The area is high and very worn so that no growth lines or transverse striations are preserved. It has the same recurving to the cardinal margin as noted by Hosking in the description of the holotype. The pseudo-deltidium is narrow and parallel-sided; it has twisted, with the twisting of the umbo, to the left. An indentation of the valve, as the beginnings of a median sinus, occurs near the anterior margin. The ornamentation of the pedicle valve is of fine forward-projecting spine bases.

The brachial valve is flat and is without an upturned margin. The median septum crosses two-thirds of the length of the shell. The surface of the valve is roughened by weathering, but numerous pits indicate the former presence of spines.

A much larger specimen, F 37710, is a pedicle valve with a high undistorted area. The valve has the same recurved margin and ornamentation as seen in the type. The median sinus is well-developed anteriorly, but is faint on the visceral portion of the shell. The area is wide and longitudinally striate; the pseudo-deltidium is narrow, parallel-sided and bears nodular perforated tubercles; it is short, continuing for only half the width of the area so that a large open space occupies the centre of the cardinal margin (filled, when the brachial valve is in position, by the triangular extension of the cardinal margin). This specimen differs from the type in size and in the possession of deltidial spines. Although no intermediate forms are known it is impossible to separate the specimen on those grounds alone. The deltidial spines are rarely present in species of *Aulosteges* and their absence may be due to removal by weathering rather than to a difference in development.

Remarks.—The distinctive feature of this species is the sharp recurving of the area, a feature not seen in other species of the genus.

The appearance of a larger shell with the same characteristics as those described for *Aulosteges spinosus* nullifies the suggestion of Hosking (1931, p. 19) that this species was possibly only the young form of *Aulosteges ingens* Hosking.

STROPHALOSIA King 1844.

1844.—King, *Ann. Mag. Nat. Hist.*, XIV, p. 313.

Genotype.—*Orthis excavata* Geinitz, Ueber einige Petrefacte des Zechsteins und Muschelkalks. *N. Jb. Min. Geol. Paläont.* 1842, p. 578 Taf. x figs. 12, 13.

Diagnosis.—Small to medium-sized shells. Concave to platy-convex dorso-ventrally with well-developed areas on both valves. Umbo distorted by cicatrix of attachment. Ornamentation essentially lamellar, lamellae usually interrupted by spines on pedicle valve; spines rarely present on brachial valve.

Pedicle valve with teeth fitting into sockets of bachial valve. Brachial valve with median septum, non-dendritic muscular impressions and pronounced brachial impressions. Trifid cardinal process well-developed.

Description.—The members of the genus *Strophalosia* are never large shells; they vary in shape from longitudinally to transversely oval, with the hinge-line equal to or slightly less than the greatest width of the shell. The pedicle valve is usually evenly convex, rarely geniculate. The brachial valve is, however, usually geniculate, being flat or concave in the visceral portion with upturned lateral and anterior margins. Both valves possess a distinct area, that of the pedicle valve being the larger. There is no open delthyrium, a pseudo-deltidium being always present.

Strophalosia has been described as a spinose Productid with an area. This description is, however, a little restricted, as all species of *Strophalosia*, for example *Strophalosia kimberleyensis* mihi, do not possess spines. The characteristic of the ornamentation is rather its lamellar structure. The lamellae are usually distinct, their outer surfaces and edges forming the external shell surface. This distinctness of the lamellae indicates that in the

members of the genus shell formation was limited, probably by physical conditions, to certain times of the year, the periods of shell deposition being separated by intervals of quiescence during which no shell was deposited. That this response to physical conditions is a generic characteristic rather than due to abnormal physical conditions may be inferred from a study of forms living under the same physical conditions in which the lamellar structure is not seen.

Spines are often present; these may be recumbent or erect, many or few; they may be of two series or uniform in size, and are usually present on the pedicle valve, though but rarely found on the brachial valve.

Internally, the structures of the brachial valve are characteristic of the genus, and the changes within the genus are largely reflected in the structure of this valve. A median septum is always present, varying in length from one-third to two-thirds of the length of the visceral portion of the valve. It separates the non-dendritic adductor muscle impressions which vary in position but show no relation in their variation to the length of the median septum. The adductor impressions are usually divided into anterior and posterior adductors, but sometimes (e.g. *Branxtonia*) no such division is seen.

The brachial impressions arise at the side of the adductor muscle scars and vary in position with the position of the muscles. Where the muscles are medial or lower in the valve, that is, towards the anterior margin, the brachial impressions run almost parallel to the hinge-line and curve abruptly to the median septum, the condition seen in the *Productus* group. Where the adductors are situated higher in the valve the brachial impressions are found near the cardinal and lateral margins and approximately parallel to them.

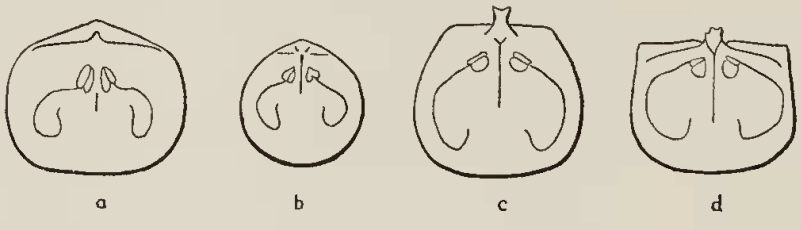

Figure 6.

Internal Features of Brachial Valves—to illustrate the alteration in position of the Brachial Impressions. (a) **Productus latirostratus,** (b) **Strophalosia lamellosa** var. **humbletonensis,** (c) **Str. jukesi,** (d) **Str. kimberleyensis.** (a), (b) and (c) after Davidson (×½).

The cardinal process, while it varies in minor details, retains throughout the genus, its typical trifid character. The process is always a compact one, the three parts being on the same horizontal level, in contrast with some Productids, e.g., *Taeniothaerus subquadratus*, where the central lobe is raised above the lateral lobes. The structures at the base of the process vary; this variation will be discussed later (p. 39).

In the pedicle valve the adductor impressions are non-dendritic, central and varying in their position in the valve as do those of the brachial valve. The diductor impressions surround those of the adductor muscles and are longitudinally striate.

In life the shells of this genus were probably orientated with the heavier pedicle valve resting on the substratum, the curvature of this valve and the upturned margins of the brachial valve keeping the open edges of the shell above the level of disturbed water. The umbonal cicatrix shows that the

shell was attached at some period, but it is not known for what length of its life the shell maintained this position. If the shell was fixed only by cementation the period of attachment was probably short as no specimens are known with the shell in this position nor are they usually broken across the umbonal region as one might expect. If, however, a process of the mantle aided cementation during life the shell would fall after the death of its inhabitant. There are no indications to show that such a process or processes existed, and one must conclude, in the absence of evidence to the contrary, that the *Strophalosias* were attached only during the earlier stages of growth.

Remarks.—The large variation within the genus *Strophalosia* is undoubtedly due to the rate of adaptation in the different species to the sedentary mode of life.

In *Strophalosia lamellosa* var. *humbletonensis* the shell shows a clear resemblance to *Productus* in the arrangement of the musculature and brachial impressions. The adductor muscle impressions are central and the brachial impressions have a distinctly Productid aspect (see fig. 6, p. 38).

If a form such as this assumed a sedentary mode of life with the point of attachment beneath the umbo, it is obvious that the structure is mechanically unsound, as the muscles in working, will be pulling against the point of attachment. To overcome this instability the muscles would tend to move backwards in the shell until they came to rest over the scar of attachment. This posteriorly directed movement of the muscles would push all those structures posterior to them backwards, and these would thus tend to atrophy or be replaced by the originally more anterior elements. The backward movement of the muscles necessarily causes an alteration in the position of the brachial impressions, as already seen (see p. 38).

In *Strophalosia* species with anteriorly placed muscle impressions, two oblique ridges arise, one on each side of the median septum, beneath the umbo and continue antero-laterally at an angle of about 45° to the hinge-line. As the muscles move posteriorly these ridges become displaced and gradually become the horizontal cardinal ridges as seen in *Str. kimberleyensis* mihi. They also impinge on the hinge-line so that the base of the cardinal process has different appearances according to the stage of movement of the muscles.

Licharew (1937, p. 127) states that the extreme condition of this movement is that shown by the Russian specimens in which the ridges have been pushed beyond the hinge-line, taking with them the sockets. The species to which Licharew refers, *Str. fragilis* and *Str. horrescens*, have dentritic muscle impressions and must be placed as members of the genus *Aulosteges*. Moreover, examination of the cardinal process of *Str. horrescens* shows that it has the typical trilobate structures and is not bifid, as might be expected if its mode of formation was as stated by Licharew. The backward movement of the ridges does change the form of the base of the cardinal process, but I have seen no specimen in which they replace it. The poor condition of the specimens of *Str. clarkei* figured by Etheridge (1880) led Licharew to think that this series of changes took place within that species. *Str. clarkei* does represent an advanced stage, in that the muscle impressions are high and the ridges have come to assume a position almost parallel to the hinge-line but the cardinal process has not been affected and the dental sockets are deep.

Comparison with other genera.—*Strophalosia* may be distinguished from both *Aulosteges* and *Productus* sensu lato by many features. In general,

Strophalosia has a well-developed area on each valve, *Aulosteges* on the pedicle valve only, while *Productus* is without a true cardinal area. This distinction does not, of course, hold for all the *Productus* subgenera, in some of which, a cardinal area is developed. The non-dendritic adductor muscle impressions serve, however, to distinguish *Strophalosia* from both *Aulosteges* and *Productus* as in these genera the adductors are always dendritic. The posterior movement of the muscles and consequent change in pattern of the brachial impressions is also a typical Strophalosoid feature.

Subgenera.—In recent years there has been much work done on the species of this genus, and it has now been subdivided into five subgenera:—

ETHERIDGINA Oehlert (= **LEPTALOSIA** Dunbar & Condra)
STROPHALOSIINA Licharew
STROPHALOSIELLA Licharew
WYNDHAMIA Booker
HETERALOSIA King

and with *Aulosteges* as a possible sixth or alternatively as a synonym. The relation of *Aulosteges* and *Strophalosia* has already been discussed (p. 34).

Etheridgina includes those *Strophalosias* in which the shell is attached throughout the life of the animal, both by embracing spines and directly by the pedicle valve. A small cardinal area and teeth are sometimes, though not always present. *Leptalosia,* to include those forms possessing an area and teeth, cemented directly by the pedicle valve, was founded by Dunbar and Condra in 1932. Examination of the type specimens of *Etheridgina complectens* (Eth. fil.), the genotype of *Etheridgine* shows, however, that some of these specimens possess the hinge structures thought to be typical of *Leptalosia. Leptalosia* becomes, therefore, a synonym of *Etheridgina.* This question is more fully discussed under *Etheridgina.*

The genotype of *Strophalosiina* Licharew is *Aulosteges tibetius* Diener. This species undoubtedly belongs to *Aulosteges* and is, under this system of classification, regarded as a subgenus of *Aulosteges.*

Strophalosiella Licharew with genotype *Strophalosiella coraeformis* Licharew is a very doubtful genus. The specimen figured and described by Licharew is a plicate form ("a *Strophalosia* with Linoproductid ornamentation") with well-developed areas on both valves. In the absence of any knowledge of the internal structure it seems impossible to assign this specimen to the genus *Strophalosia.* Until this knowledge is available it would seem better to maintain it as an independent genus of unknown affinities.

Wyndhamia was founded by Booker in 1929 for the reception of a group of Strophalosoid forms with adductor muscles undifferentiated into anterior and posterior elements and without evidence of a period of attachment. The position of the muscle scars (placed posteriorly in the valve) would indicate that the species of this subgenus (*W. valida* Booker and *W. dalwoodensis* Booker) had attached ancestors, and had retained some of the ancestral characteristics, although they themselves had ceased to be attached. The assumption of these distinctive features, undifferentiated adductor muscle scars and absence of a cicatrix, is sufficient to characterise the subgenus. The type species of the subgenus is *Wyndhamia dalwoodensis* Booker from Permian beds of Branxton, New South Wales.

In the same paper (1929, p. 30) Booker also proposed a new subgenus *Branxtonia* of *Productus.* The author has not been able to see the specimens of the genotype, *Branxtonia typica* Booker, but from Booker's own figures and similar specimens from Western Australia, suspects that the specimens

are Strophalosias. They show the same structure and arrangement of the muscle scars in the brachial valve, and the impression of dental callosities may be seen on the casts. The specimens do not show an area, but until specimens with some shell preserved are seen it is impossible to say that its absence is not due to thickening of the hinge-line behind the area. If no area is present then *Brauxtonia* must be regarded as an attached form or of a line of attached Productids with consequent muscle movement as in *Strophalosia*.

Heteralosia King (1938, p. 278) with genotype *H. slocomi* King is distinguished from *Strophalosia* s.s. by the possession of a non-spinose brachial valve. It seems doubtful whether a division of the *Strophalosias* based on the ornamentation of one or the other valve is of great advantage, and although of the species here described *S. etheridgei* and *S. gerardi* (?) would be placed in *Heteralosia* I have left them in *Strophalosia* s.l. If King's division is accepted, a new genus, without spines on either valve, must be proposed to include *S. clarkei* and *S. kimberleyensis*.

Strophalosia cf. Strophalosia beecheri Rowley.

Pl. v, figs. 1-3.

1893.—*Strophalosia beecheri* Rowley, p. 308, pl. 14, figs. 18-19.
1908.—*Strophalosia beecheri* Rowley, p. 76, pl. 17, figs. 24-25.
1914.—*Strophalosia beecheri* Rowley, Weller, p. 146, pl. xix, figs. 37-38.

Material.—U.W.A. 20449, one specimen—conjoined valve; Waltharrie Pools, Wooramel River District; Callytharra Limestone.

Diagnosis.—Shell small, almost circular in outline, hinge-line slightly less than greatest width of shell. Surface ornamentation of erect spines of approximate quincuncial arrangement and fine growth lines.

Pedicle valve convex, asymmetric without sinus though flattened medially and sloping steeply anteriorly and laterally. Cicatrix large, placed on one side of umbo. Area as long as hinge-line, flat and triangular. Pseudodeltidium triangular. Teeth short and diverging.

Brachial valve concave, area distinct, almost as large as that of pedicle valve, pseudo-chilidium large and triangular.

Internal features not known.

Description: *Dimensions of Specimen.*

Height	12.6
Maximum breadth	12.6
Length of hinge-line	8.8

Specimen too crushed to give accurate measurement of thickness.

The pedicle valve of this specimen is asymmetric due to the large cicatrix of attachment on one side of the umbo. It is evenly swollen in the middle with the sides and the front sloping steeply giving it a somewhat squashed appearance. The ears are small and flat with obtuse cardinal angles. The specimen is unfortunately badly weathered so that the ornamentation is obscured. Slender erect spines with approximate quincuncial arrangement are the obvious feature of the ornamentation, the concentric shell laminae of the original shell surface, if these were present, being obscured. The

area is flat and lies in the plane of the commissures; it is interrupted by a triangular slightly convex pseudo-deltidium. Owing to the crushing of the brachial valve, the teeth are seen to be short, stout and diverging.

Even in its uncrushed form, the brachial valve must have been very concave. The ornamentation cannot be seen at all unless some pits due to weathering indicate that it was spinose. The area of this valve is as large as the pedicle area, with a well-developed pseudo-chilidium.

Comparison with other species.—This specimen resembles *Strophalosia beecheri* Rowley (Weller 1914, p. 146, pl. xix, figs. 37-38). Weller, in his description of this species, quotes its asymmetric character as a diagnostic feature. From his figure 37 it would appear that in that species, as in this specimen, the asymmetry is probably due to the cicatrix on one side. It is, however, a broader form than the present species and Weller says broader than long; but as he, too, had only one specimen, the variation within the species is not known.

Remarks.—This specimen has been compared to *Strophalosia beecheri,* but not identified finally as a member of that species since further specimens are required, both from America and Western Australia, before any definite identification is possible. More specimens, too, may establish the present specimen as a member of one of the variable Western Australian species.

Strophalosia clarkei (Etheridge).

Pl. v, fig. 4.

1872.—*Productus clarkei* Etheridge, p. 334, pl. xvii, figs. 2, 2a, 2b; pl. xviii, figs. 4, 4a.

1877.—*Productus clarkei* Etheridge, de Koninck, p. 203, pl. x, fig. 5; pl. xi, fig. 3.

1878.—*Productus clarkei* (Etheridge), Etheridge, jun., p. 51.

1880.—*Strophalosia clarkei* (Etheridge), Etheridge, jun., p. 289, pl. ix, figs. 18-21; pl. x, figs 22-28; pl. xi, figs. 29-31; pl. xii, figs. 32, 33.

1892.—*Strophalosia clarkei* (Etheridge), Etheridge & Jack, p. 258, pl. xiii, figs. 12-17; pl. xiv, fig. 19.

Holotype, belonged to Daintree Collection. Present location of type specimen not known.

Other Material.—B.M. B 5885, Capertree, N.S.W. (figured by Etheridge, 1880). Aus. Mus. F 36234, 36235, Jimba Jimba, near Mooka Springs, North-West Division. Gascoyne series.

Diagnosis.—Shell transversely oval to subquadrate, hinge-line less than greatest shell width. Pedicle valve inflated, without median sinus. Brachial valve flat to concave. Ornamentation of silky laminae on both valves.

Interior of pedicle valve with thin median ridge separating dendritic adductor muscle impressions. Diductors large, flabellate and longitudinally striate. Teeth large.

Brachial valve with strong cardinal process continued into long median septum. Dental sockets large and oblique. Adductors high in valve. Brachial impressions strong, following edge of valve; valve geniculate with marginal rim perpendicular to visceral disc. Line of three depressions (adductor scars, depression below muscle scars and ends of brachial impressions) on each side of median septum.

Description.—Little can be added to the descriptions of this species in Etheridge (1880) and Etheridge and Jack (1892). The two specimens from Jimba Jimba are brachial valves whose external features are obscured by matrix. The internal features are as described by Etheridge. The characteristic structures of the valve are the line of three depressions (those of the adductor impressions, depression below the muscles and ends of brachial impressions) on each side of the median septum and the groove and marginal ridge on the outside of the brachial impressions. Inside the brachial impressions the shell is raised and prominent.

Comparison with other species.—The differences between this species and *Strophalosia kimberleyensis* mihi will be found under the heading of the latter species.

Etheridge (1880, p. 296) suggested that *Strophalosia gerardi* King and *Strophalosia clarkei* (Etheridge) were possibly one and the same species. The absence of any reliably identified specimens of *Str. gerardi* showing the internal characters led him to postpone a final decision in the matter. The situation of *Str. gerardi* is still the same, but these species may be distinguished by their external characteristics. *Strophalosia gerardi* has a relatively much shorter hinge-line, and its external ornamentation of oblique adherent spines on coarse concentric lamellae distinguishes it from the smoothly silky surface of *Str. clarkei*. Etheridge (1872) described the ornamentation of *Str. clarkei* as "covered with fine, vertical, wavy lines, projecting from which are numerous slender spines." This ornamentation I have not seen, weathering having removed apparently both the vertical lines and the spines. However, the description would certainly not fit the coarse adherent spines of *Str. gerardi*.

Strophalosia etheridgei n. sp.

Pl. v., figs. 5-12.

Syntypes.—G.S.W.A. 1/5242 (a), creek, ½ mile west of Callytharra Springs, Wooramel River. Callytharra Limestone.

Topotypes.—G.S.W.A. 1/5242 (b), same locality and horizon.

Other Material.—U.W.A., 20267, Fossil Cliff, Irwin River. Fossil Cliff horizon. U.W.A., 20247, Fossil Ridge, Irwin River District. Fossil Cliff horizon. Aus. Mus. F 38463, 38464, 38448, Wandagee Station, Minilya River, North-West Division. Wandagee stage.

Diagnosis.—Shell small, thin, transversely-oval to almost circular in outline. Hinge-line less than greatest width.

Pedicle valve flattish, evenly convex, non-sinuate, area relatively wide with narrow but not prominent pseudo-deltidium. Ornamentation of adherent spines interrupting silky laminated surface structure. Umbo not prominent, area of attachment small. Teeth small and diverging. Muscle scars deltoid in outline, non-dendritic, almost under umbo.

Brachial valve flat in visceral region with upturned margins. Ornamentation of silky laminae and concentric wrinkles. When weathered, valve pitted anteriorly. Cardinal process inclined, continued into short median septum. Sockets prominent, inclined at high angle. Muscle impressions rounded, at base of cardinal process.

Description.—The small size of this species is shown by the table of dimensions:—

——	Maximum width.	Length hinge-line.	Height.	
Syntypes :				
1. Conjoined valves	8·0	4·6	6·5	
2. Pediele valve	8·5	5·7	7·0	
3. Brachial valve	6·7	5·0	5·4	
4. Conjoined valves	9·0	6·2	8·0	
Irwin River Specimens :				
1. Fossil Ridge	10·8	6·8	8·5	
	7·1 +	4·2	7·1	Brachial
2. Fossil Cliff	10·4 +	5·6	9·4	Valves
	8·9 +	5·3	8·4	
	15·9	11·0	15·4	Pediele Valve

The pedicle valve is small, thin-shelled and moderately inflated; it diminishes in convexity gradually towards the lateral and anterior margins, somewhat suddenly towards the cardinal margin. The area is small, narrow and triangular, its length less than that of the hinge-line. The shell substance is lamellar and has a silky texture, the laminae interrupted by the spines, which closely adhere to the surface of the shell. A few erect spines are present on the ears. The muscle scars are situated high up in the valve and have a deltoid outline, the delta divided medially by a groove into the two triangular areas. They are non-dendritic.

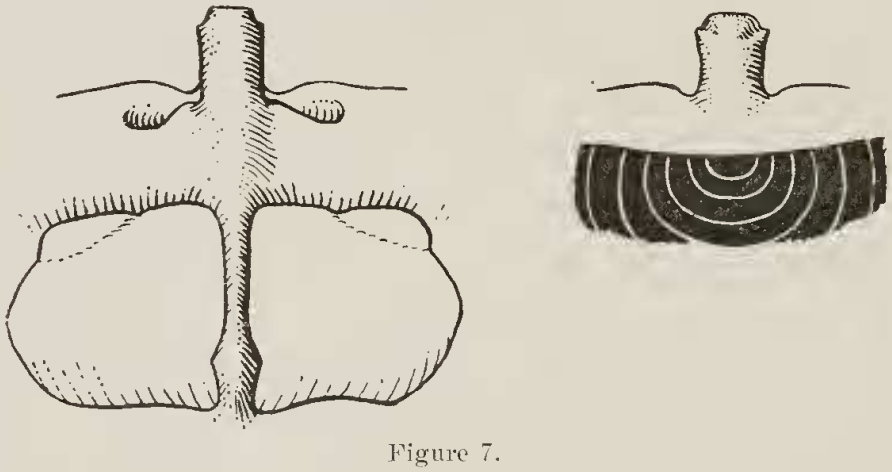

Figure 7.
Cardinal Process of **Strophalosia etheridgei** n. sp. (×11).

The brachial valve is flat in the visceral region with geniculated margin and has a silky laminated and imbricated surface. The hinge-line is short and the cardinal angles are obtusely rounded. The area is distinct, triangular with the umbonal angle flattened; the pseudo-chilidium is triangular and wide with two deep, narrow sockets, inclined to the median septum at its base. The cardinal process is narrow near the hinge-line, but swells out to a

bulbous top. This is, however, usually worn down so that the process appears to continue posteriorly at an even width. The semi-circular visceral portion of the brachial valve is interrupted by the short median septum, which is swollen between the rounded muscle impressions. The valve is hollowed out below the sockets and in a direction parallel to the hinge-line, a ridge separating this hollow from the cardinal margin.

Comparison with other species.—The small size of these specimens distinguishes them from any species of *Strophalosia* so far described from Western Australia. They were labelled by Miss Hosking in the Geological Survey Collection, as being young specimens of a new species. The geniculated margin of the brachial valve indicates, however, that they are probably in the adult or nearing the adult condition unless they are the young forms of a *Proboscidella*-like *Strophalosia*. In the absence of any shells which might be assigned to such subgenus I have described them as adult forms.

Many features of these shells are also common to *Strophalosia clarkei* Eth. fil. and *Strophalosia gerardi* King, although they cannot be regarded as closely related to either of those species. The brachial valve particularly, with its silky lamellar structure, short hinge-line and rounded alar angles, resembles *S. clarkei*. The pedicle valve, however, would distinguish them at once from that species in its ornamentation showing a marked resemblance to *S. gerardi;* from young members of this species they would be distinguished by the shape and convexity of the pedicle valve.

Strophalosia gerardi King.

Pl. v, figs. 13, 16, 17.

1846.—*Strophalosia gerardi* King, p. 93 footnote.

1847.—*Strophalosia gerardi* King, de Koninck, p. 137.

1850.—*Strophalosia gerardi* King, p. 96, pl. xix, figs. 6-7.

1857.—*Strophalosia gerardi* King, Davidson, Introduction, pl. viii, fig. 211.

1880.—*Strophalosia gerardi* King, Etheridge, jun., p. 294, pl. xii, figs. 34-37; pl. xiii, fig. 38.

1884.—*Strophalosia gerardi* King, Etheridge, jun., p. 87.

1892.—*Strophalosia gerardi* King, Etheridge & Jack, p. 260, pl. xiii, fig. 18; pl. xiv, fig. 18; pl. xl, figs. 7-8.

1932.—*Strophalosia gerardi* King, Reed, p. 20, pl. i, fig. 7.

Material.—Holotype. Univ. Coll. Galway, I.F.S., No. F.C.D. 267.

Diagnosis.—Shell outline transversely oval. Pedicle valve convex, nonsinuate; brachial valve concave following outline of pedicle valve. Ornamentation of concentric lamellae and adherent tapering spines. Area on both valves with pseudo-deltidium and pseudo-chilidium. Length of hinge-line less than maximum width of shell.

Pedicle valve swollen, with greatest convexity in visceral region, nongeniculate. Cardinal angles obtuse, ears small.

Brachial valve concave, greatest concavity near umbo, shell sloping thence gradually to all margins.

Internal features unknown.

Description of specimen.—Univ. Coll. Galway, F.C.D. No. 267. Viewed from the brachial side the shell is a regular oval in outline, the transverse axis passing postero-anteriorly. From the pedicle side it has rather a triangular aspect.

The pedicle valve is flatly convex, the maximum convexity behind the umbo, thence flattening gradually to the anterior and lateral margins and steeply to the cardinal margin. The area is short, equal in length to half the maximum width of the shell; it is relatively high with a very narrow, almost straight-sided pseudo-deltidium. The area of attachment is large, and has the appearance of callus over the shell surface. The ornamentation of the pedicle valve is essentially spinose, the spines adherent, with an irregular quincuncial arrangement. The structure of the shell surface is lamellar though the lamellae are largely obscured.

The brachial valve is concave. It slopes steeply from the umbo to the middle of the shell, thence following the curve of the pedicle valve. The shell structure is lamellar, but the valve is weathered, and no spine bases are seen, the ornamentation consisting of the truncated lamellae and irregularly spaced nodules. The area of the brachial valve is narrow but distinct. Internal features not shown.

Dimensions.

Height	30.4
Maximum breadth	38
Thickness	10.8

Etheridge says (1880, p. 296) that he finds "what appears to be the bases of insertion of spines" on the brachial valve of King's type specimen. It is difficult to come to a decision on this point from a study of the type specimen alone as, although there are hollows and small prominences on the lamellae, it seems almost impossible to decide that these prominences are or were spine bases. They show no concentric structure and no sign of aperture. It is noticeable, however, that where the spine bases are worn down on the pedicle valve, they, too, show no structure. On his figures of the Queensland specimens, too, Etheridge figures no specimen with spines on the brachial valve.

Strophalosia sp. cf. **Str. gerardi** King.

Pl. v, fig. 14, 15.

Material.—U.W.A., 12399. One pedicle valve. Fossil Cliff, Irwin River. Fossil Cliff horizon.

Description.—The shell is convex, non-geniculate, with the greatest convexity in the visceral region behind the cardinal margin. From this area of maximum convexity the surface slopes gradually to the anterior and posterior margins, but more steeply laterally. A large cicatrix covers the umbonal region. The area is concave with a well-marked pseudo-deltidium, at the base of which arise strong diverging teeth. The length of the area is about half the maximum breadth of the shell.

Dimensions.

Maximum width	31.7
Length of hinge-line ..	15.3
Height	27.0
Length of pedicle valve ..	38.9

The shell surface is lamellar with strong oblique spines arranged in irregular concentric rows. Posteriorly and on the cardinal slopes the spines are small and adherent; they become larger towards the anterior margin.

Internally the adductor impressions are seen high up in the valve; they are separated medially by a narrow groove. Longitudinal striations mark the shell at the side of the adductor impressions and are probably the impressions of the diductor muscles.

Comparison with other species.—This specimen has been referred to *Strophalosia gerardi* rather than identified with it. The general outline of the Irwin River shell is much broader than any specimen of *Str. gerardi,* and the spines are more widely spaced and less oblique than in that species. This specimen is possibly a local variant of *Str. gerardi,* but in the absence of intermediate forms cannot be satisfactorily united with it.

Strophalosia jukesi Eth. fil.

Pl. v, figs. 18-20.

1880.—*Strophalosia jukesi* Eth. fil., p. 307, pl. xiii, figs. 39-43.
1888.—*Strophalosia jukesi* Eth. fil., Johnston, pl. xiv, fig. 7.
Syntypes.—B.M. 96874, 96931. New South Wales. Exact locality and horizon unknown. Figured by Etheridge 1880, pl. xiii, figs 39-43.
Other Material.—Commonwealth Palaeontologists' Coll. P. 14. Talbot's Cairn, Wooramel River District. U.W.A., 20264, same locality and horizon. U.W.A., 20266, same locality and horizon.

Diagnosis.—Shell elongate-oval in outline, hinge-line less than maximum shell width. Ornamentation of spines and concentric lamellae on both valves.

Pedicle valve evenly convex with flattening towards anterior margin and steep slope to cardinal margin. Area wide and distinct, pseudo-deltidium triangular. Ears small. Cardinal angles obtuse. Muscles high in valve, adductors central and compact, diductors flabellate and longitudinally striate.

Brachial valve concave, greatest concavity in front of umbo. Area distinct, half as wide as area of pedicle valve. Adductor muscle impressions divided into anterior and posterior sections. Cardinal process large, trifid, continuing into strong median septum.

Description.—A number of ferruginous casts have been referred to this species, as they agree in all particulars with Tasmanian specimens. For a complete description of the species see Prendergast (*Proc. Roy. Soc. Tasmania*).*

Strophalosia kimberleyensis n. sp.

Pl. vi, figs. 1-5.

1890.—*Strophalosia clarkei* Etheridge, Foord, p. 103, pl. v, fig. 7-8, text-fig. 6.
1903.—*Strophalosia* sp. ind. Etheridge, jun., p. 20, pl. i, figs. 10-12.
Holotype.—U.W.A. 20452 north of Hill C, south side of Grant Range, Kimberley Division. Upper Ferruginous Series.
Paratypes.—U.W.A. 20460, same locality and horizon.
U.W.A. 20455, Nooncanbah Homestead, Kimberley Division. Nooncanbah Series.
Topotypes.—U.W.A. B 127.
Other Material.— B.M. B 4590, 4591, south-east of Mt. Abbott, on Fitzroy River, Kimberley Division. Horizon unknown. (Figured by Foord 1890). W.A. Mus. F 166 (4744), Cookilya Pool, Wandagee Station, Minilya River. Wandagee stage. (Figured by Etheridge, 1903). W.A. Mus. △ 12, south-east of Mt. Abbott, Fitzroy River, Kimberley Division. Horizon unknown. Aus. Mus. F 37523-37529; Minilya River. Wandagee stage. Aus. Mus. F 36221-36225, Jimba Jimba Station, Gascoyne River. Byro stage. U.W.A. B. 51. Nooncanbah Homestead, Kimberley Division. Nooncanbah series.

Diagnosis.—Shell subquadrate to ovate in outline, pedicle valve inflated to hemispherical, brachial valve evenly concave, hinge line almost greatest width of shell.

Pedicle valve with lamellar concentric ornamentation; cardinal area elongate triangular with small triangular pseudo-deltidium. Internally with strong teeth, valve thickened postero-laterally with strong ridges bounding visceral portion laterally. Adductor muscles non-dendritic, narrow, on each side of median line; diductors longitudinally striate arising in front of adductors and extending from near middle line to lateral margin. Muscles set in distinct fossae.

Brachial valve with ornamentation as in pedicle valve. Valve thickened anteriorly, regularly concave exteriorly but geniculate interiorly. Cardinal process trifid, strong, with sockets at base; sockets separated by diagonal ridges from depressed muscular area. Posterior adductors elongate laterally, anterior adductors elongate antero-posteriorly. Brachial impressions arising from lateral edges of posterior adductors, following lateral and antero-lateral margins then turning backwards towards median septum. Septum continuing about two-thirds length of valve. Cincture separating visceral disc from trail.

Description of Holotype.—The holotype is an almost complete specimen with both valves in position. The pedicle valve is unfortunately weathered so that the external shell layers are absent. The valve is thick and of lamellar structure. The area is long and triangular, its width equal to one-fifth of its length; it has a narrow, closed, triangular delthyrium. The brachial valve is regularly concave and is ornamented by concentric lamellae, the edges of the lamellae forming the shell surface. It has a narrow area disposed almost at right angles to that of the pedicle valve.

Description of Paratypes.—The paratypes are two specimens, one a pedicle valve, the other a brachial valve, selected to show the internal features of the species.

In the pedicle valve (20460) the teeth are strong and diverging from the hinge-line; laterally they are joined to a projecting ridge separating the ears from the visceral cavity. The shell is thickened in the region of the ears, the ridge continuing as a platform to the lateral margin, its continuity being broken up by a narrow groove behind the ridge. This groove serves as a socket, a ridge on the brachial valve fitting into it. The muscle marks are distinct, the adductors elongate on each side of the middle line, arising almost under the teeth. The diductors are large, longitudinally striate, and anterior to the adductors they are separated by a rounded prominence in the middle line.

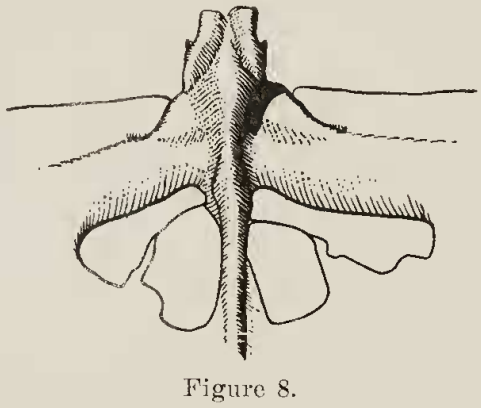

Figure 8.
Cardinal Process of **Strophalosia kimberleyensis** n. sp. (×3).

The interior of the brachial valve (20455) is geniculate, due to thickening of the lamellae in this region, a narrow groove (cincture) separating the visceral disc from the trail. In the visceral part the valve is almost divided by the median septum which continues forward for two-thirds of the length of the visceral disc; it is continued posteriorly as a trilobate cardinal process, at the base of which are deep sockets. The adductor muscles are below the sockets and set in a depression which gradually decreases anteriorly (this depression is bounded posteriorly by a ridge parallel to the hinge-line). The anterior adductors are elongate postero-anteriorly. The posterior adductors are elongate laterally and from their lateral extremities arise the brachial impressions. These continue the line of the ridge below the sockets until they almost reach the lateral border, they then follow the lateral and antero-lateral margins of the visceral disc and turn upwards parallel to the median septum. They cannot be traced in this specimen beyond the level of the end of the median septum.

Dimensions of Shells.

	Height.	Curvilinear length of pedicle valve.	Length of hinge-line.	Max. width.	Thickness.
Holotype	28·2	56·0	22·0	27·8	10·8
Paratypes—					
20460	19·2+	31·0+	23·7	30·0	....
20455	24·3	....	24·5	29·3	....
Brachial Valves	29·3	....	29·4	35·7	....
	25·0	....	25·2+	28·1	....
Combined Valves	24·9	43·0	23·9	28·5	14·5
	29·0	46·0	25·9	28·8	14·4
	25·0	42·0	24·5	28·7	9·8

As may be seen from these figures, the height and width of the valve are the same in full-grown specimens, but as the maximum width is situated in the posterior half of the shell, younger specimens are wider than long.

The pedicle valve varies in shape from quadrangular to almost semicircular and in convexity from weakly convex to hemispherical. As the shell becomes more strongly curved with age, the convexity is an indication of the age. There is, too, a difference in shape of some of the brachial valves due to the varying amount of thickening anteriorly; thus the valve may be regularly concave or slightly geniculate.

Owing to decortication of the shell surface, it is impossible to describe the true ornamentation of the shells. The lamellae are distinct on both valves and some specimens of the brachial valve show that these are crossed by very fine radial striae. A few only of these are seen, but they are continuous from one lamella to the next. One pedicle valve has, also, a small patch of radial ornamentation preserved. It is possible, therefore, that, were the shell surface preserved, the shell could be described as radially striate; alterna-

tively the radial markings may be the result of weathering. No pits, such as would indicate the presence of spines, have been observed and it would seem, therefore, that this species is non-spinous.

The variation within the species is also reflected in the internal structure of the brachial valve. The median septum may be equal in length to half or increase up to two-thirds of the length of the visceral disc. The brachial impressions may follow closely the lateral margin or be placed some distance from it.

Remarks.—The most peculiar characteristic of this species is the nature of the visceral cavity, the thickened region of the ears and the ridge projecting into the cavity. This may be seen externally, when the brachial valve becomes squashed in, showing the shape of the cavity.

Comparison with other species.—I regret that I have been unable to trace the type of *S. clarkei* (Eth.), which belonged to the Daintree Collection. Externally this species resembles *S. clarkei,* though it differs in many respects, as Etheridge (1903, p. 21) has already pointed out. With more and better specimens many of these distinctions cannot now be maintained, but this species, *S. kimberleyensis* is distinct in the depressed umbonal region, relatively longer hinge-line and concave rather than flat brachial valve. Internally, it occupies a position intermediate between *S. clarkei* and *S. jukesi.* In *S. clarkei* the median septum is as long as the visceral disc and the brachial impressions are transversely elongated; in *S. jukesi* the septum is short and the brachial impressions narrow. Thus in *S. kimberleyensis* with short median septum and wide brachial impressions we see a species with characters of both the other species. Externally the species is distinct from *S. jukesi* and *S. gerardi* in the absence of spines.

Strophalosia multispinifera n. sp.

Pl. vi, figs. 6-8.

Holotype.—U.W.A. 20458. Scarp two miles east of Christmas Creek Homestead, Kimberley Division. Nooncanbah Series.

Topotypes.—U.W.A. B 74. Same locality and horizon.

Other Material.—U.W.A. 20456, Hill C., south of road, Grant Range, Kimberley Division. Nooncanbah Series.

Diagnosis.—Pedicle valve large, swollen, transversely oval in outline, hinge-line less than greatest width of shell.

Ornamentation of fine oblique spines with regular quincuncial arrangement; group of spines on each ear. Valve with elongate area, triangular delthyrium. Cicatrix small. Teeth large. Brachial valve unknown.

Description.—The pedicle valve is evenly convex with a slight median depression, not sufficiently marked to be termed a sinus. It is 45 mm. high, with maximum width of 49.6 mm., while the hinge-line is 34.8 mm. long. The surface of the valve is marked by closely spaced spine bases arranged in irregular quincunx; it is probable that these gave rise to small forward projecting spines, but no spines are preserved on the body of the shell. The spines have a density of 6 in 10 mm. measured transversely at a distance of 20 mm. from the umbo. The spines become more closely packed on the ears to give a compact group at each end of the hinge-line. They are closer together and more irregular anteriorly. The area is short, its width approximately half its length; it is longitudinally striated and interrupted by a

pseudo-deltidium which is not raised above the general surface of the area. Only one tooth has been seen; this is large and rounded with the concavity towards the lateral border.

The umbo is not prominent, having been absorbed by the cicatrix of attachment; this is small and usually almost perpendicular to the surface of the area.

The brachial valve is unknown.

Remarks.—Within this species there is a large variation in shape, many of the shells becoming elongated. It is noticeable that in this species, as in many *Strophalosias* (e.g., *S. kimberleyensis* mihi) the shells appear very narrow in the hinge region when seen as an internal cast. This is due to the very close fitting ears which leave almost no space between those of the two valves when these are in contact.

Comparison with other species.—This species is characterised by the regularity of the spines over the body of the shells, the spine groups on the ears, the small regular point of attachment and the absence of lamellar structure. It approaches nearest to *S. tenuispina* Waagen from which it may be distinguished by the much coarser spinosity of that species and the larger size of *S. multispinifera*.

STROPHALOSIA sp. A.

Pl. vi, fig. 10-12.

Material.—U.W.A., 20448 Fossil Cliff, Irwin River District. Fossil Cliff horizon.

Diagnosis.—Shell longitudinally oval in outline, evenly curved both transversely and longitudinally. Hinge-line less than greatest width of shell. Ornamentation of lamellae with fine adherent spines concentrically arranged. Pedicle valve swollen, non-geniculate, sides sloping steeply. Area narrow, triangular. Small divergent teeth.

Brachial valve unknown.

Description.—A single pedicle valve from the Irwin River District shows distinctive characters.

Dimensions.

Height	11.9
Maximum width	11.6
Length of hinge-line	6.3
Length of pedicle valve ..	18.6

The valve is swollen with the hinge-line less than the greatest width of the shell; the shell is widest near the anterior margin. The umbo is completely obliterated by a large scar of attachment, it has become incurved so that the area now faces antero-dorsally. The spines are regularly arranged in concentric rows and are all of equal size, there being no sign of a secondary series of spines as occurs in so many of the Indian forms. The rows are widely separated and between them are the silky laminations of the shell structure.

The area is well-developed with a wide delthyrium: the teeth are large and diverging. The muscle impressions are high in the valve. The adductors are central, separated by a median ridge and enclosed on the outside by the diductors, which are flabellate and produced anteriorly.

The distinctive characters are the widely spaced concentric rows of spines combined with the elongated shape of the shell.

Comparison with other species.—This shell appears most similar to *Strophalosia rarispina* Waagen (1884, p. 645) but the pedicle valve of that species has a slight median sinus and the spines are in two series.

Strophalosia tenuispina Waagen.

Pl. vi, fig. 9.

1884.—*Strophalosia tenuispina* Waagen, p. 654, pl. lxiv, figs. 2-7.

Material.—C.W.A. 20451. One pedicle valve. Fossil Cliff, Irwin River. Fossil Cliff horizon.

Diagnosis.—Shell circular to oval in outline, hinge-line equal to maximum width, pedicle valve but slightly inflated, dorsal valve concave. Surface ornamentation finely lamellose with sparsely distributed oblique spines. Pedicle valve non-sinuate, area high, with flat, narrow linear pseudo-deltidium. Small scar of attachment.

Brachial valve with small linear area, surface ornamentation not known.

Description.—This species is known by a single specimen of a pedicle valve from the Irwin River.

Dimensions of Valve.

Height	17.8†
Maximum width	21.3†

The specimen is rather weathered, but shows the fine spines; these are represented now only as rather worn bases; the spines are all tangential to the shell surface and some of them adpressed. They are arranged more or less in concentric rows, each row separated from the previous one and that following by lamellae. On the lateral margins larger spines are developed, and these show a curious marking, almost a facet developed on the ventral surface of each spine. Whether this is the effect of weathering it is impossible to say. The spines, apart from their concentric arrangement, also show a roughly quincunxial arrangement.

The area of this species is very distinctive among *Strophalosias*, being flat and in the plane of the commissure of the valves. It is interrupted by a very narrow, parallel-sided pseudo-deltidium.

Comparison with other species.—For comparison of this species with *Strophalosia etheridgei* mihi, see account of that species.

ETHERIDGINA Oehlert.

1887.—Oehlert, in Fischer's Manuel de Conchylogie, p. 1278.

Genotype.—*Productus complectens* Eth. fil., 1876, On an adherent Form of *Productus* and a small *Spiriferina* from Scotland. *Quart. J. geol. Soc. Lond.*, p. 454, pls. xxiv, xxv.

Diagnosis.—Shell small, concavo-convex, dorso-ventrally, with semi-oval marginal contour; generally as broad as long; hinge-line less than greatest width of shell. Shell attached to foreign bodies by embracing spines or by cementation of pedicle valve. Surface ornamentation of concentric undulating wrinkles. Area primarily present, with dental sockets and teeth. Muscle scars non-dendritic.

Description.—This genus was first described from the Carboniferous of Scotland and is now also known from the American Carboniferous and the Permian of Australia. The shells are always small and vary in their mode of attachment with the nature of the foreign body which acts as host. Thus, in the Scottish Carboniferous forms, where they occur more usually on crinoids, the spines along the hinge-line are greatly elongated and embrace the stem which may grow over and completely enclose the brachiopod. In the American forms (and in the Australian) on the other hand, which attach themselves to a flat surface, the shell is cemented directly by the whole of the pedicle valve—the spines along the hinge-line being produced parallel to the surface and adhering thereto.

The area, in those forms in which it has been observed, is narrow and extends along the total length of the hinge-line. In the pedicle valve teeth may be present or as is more usual in the Scottish forms they are represented only by vestigial or rudimentary small lumps.

Discussion.—In his original description of this genus Oehlert quotes the date as 1877; this was probably an error for 1887. In founding the genus, Oehlert referred it to *Productus,* it having, he thought, in common with that genus, the absence of area and of teeth and the pedicle valve not distorted by cementation.

The definition of the sub-family *Strophalosiinae* by Schuchert (1913) as productids anchored by spines or by most part of the pedicle valve, allowed *Etheridgina,* like *Chonopectus,* to be included in the subfamily without inferring any relationship to *Strophalosia* or indeed, any similarity other than that of habitat. Greger (1920, p. 535) referred a number of small adnate American species, formerly included in *Strophalosia,* to this sub-genus but accepted it as a sub-genus of *Productus.* Careful examination of the type specimens of the genotype of this sub-genus shows, however, that it should be referred to *Strophalosia* rather than to *Productus.* Several of the co-types (Royal Scottish Museum, Nos. 5074-5083) show a small though relatively well-developed area and teeth have also been seen on one specimen. Also the adductor scars of the brachial valve are non-dendritic. These features clearly distinguish it from *Productus* and show its relationship to *Strophalosia. Etheridgina* is, therefore, placed here as a sub-genus of *Strophalosia.*

In 1932 another productid sub-genus—*Leptalosia*—was proposed by Dunbar and Condra (1932, pp. 189, 190, 260) to include adnate productids attached by the whole of the pedicle valve. The members of this sub-genus had an area and hinge teeth in the pedicle valve of the older species (the sub-genus ranged from Upper Devonian to Carboniferous) and a distinctive small productelliform cardinal process. The genotype is *Etheridgina scintilla* (Beecher) (quoted by them as *Strophalosia scintilla* although this species had been referred to *Etheridgina* by Greger in 1920). The sub-genus, according to its authors, differs from *Etheridgina* in possessing a cardinal area and in the form of its cardinal process the resemblance of the two genera being homoeomorphic and the result of a similar habit of growth.

It is worth considering these differences further. As has been already mentioned, the type species of *Etheridgina* does possess an area. Dunbar and Condra (op. cit., p. 260) describe the productelliform cardinal process as "very small and bifid, composed of two narrow posteriorly facing and

closely adpressed muscular apophyses supported in front by a pair of very short diverging ridges separated by a depression." This clear definition is somewhat marred, however, by their statement (p. 192) that "as now conceived the genus (*Productella*) is undoubtedly a "Dump-box" for primitive Productoids and includes the ancestral radicles of several later genera." Which of these radicles, then, have they selected to typify the genus? In view of Kozlowski's work (1914) on the cardinal processes of *Productus* species this is a serious omission, as he has shown quite conclusively that not only does the cardinal process vary from species to species within a genus, but also with age among the members of any one species. On the other hand, Dunbar and Condra may consider that all the species of *Productella*, even with its present "dump box" composition, have a primitive type of cardinal process which therefore may be taken as characterising the genus; in other words, that Devonian Productoids of whichever "ancestral radicle" have the same type of cardinal process. And, significant in this issue, the only members of *Leptalosia* whose cardinal processes are mentioned in the description of the species are *L. truncata* and *L. radicans*, Devonian forms. It is just possible then that Dunbar and Condra have generalised about the Carboniferous forms from work on Devonian species. We do not know whether the cardinal processes of the American Carboniferous *Leptalosias* are of the same primitive pattern and cannot, therefore, yet separate them from the Scottish Carboniferous sub-genus *Etheridgina*.

One other point which might be produced in support of the separate existence of *Leptalosia* is the presence of teeth in the species of this genus, Oehlert having defined *Etheridgina as* "without cardinal teeth." The mistake in this case is Oehlert's, one of the co-types of *E. complectens* having at least the rudiments (or vestiges) of teeth, a condition also found among the Carboniferous forms of *Leptalosia*. In the face of this evidence I cannot regard *Leptalosia* as other than a synonym of *Etheridgina*.

Etheridgina muirwoodae n. sp.

Pl. vi, figs. 14, 15.

1914.—*Strophalosia* sp. Eth. fil., p. 34, pl. v, figs. 16-18.

1918.—"*Strophalosia complecte s*" Eth. fil., p. 253, pl. xl, figs. 11, 12.

Syntypes.—Aus. Mus. F 16699, three specimens; two are pedicle valves, one shows two conjoined valves, figured by Etheridge as *Strophalosia complectens* (pl. 40, fig. 12). Balmaningarra, Mt. Marmion, Kimberley Division. Horizon not known.

Topotype.—Aus. Mus. F 16812, one pedicle valve, figured by Etheridge as *Strophalosia complectens* (pl. 40, fig. 11). Balmaningarra, Mt. Marmion, Kimberley Division. Horizon unknown.

Other Material.—G.S.W.A. 10930, Mt. Marmion, Kimberley Division. Horizon not known. G.S.W.A. 10929, north of Barrabiddy, North-West Division. Horizon not known. Aus. Mus. F 38498, 38499, Wandagee Station, Minilya River, North-West Division. Wandagee stage.

Diagnosis.—Shell small, transversely oval to subquadrangular in outline, adherent by body of pedicle valve and radiating marginal spines. Hingeline less than greatest width of shell, with rounded alar angles.

Pedicle valve with upturned lateral and anterior margins, visceral region adherent, flat. Hinge area wide and flat, pseudo-deltidium large and triangular, teeth strong, divergent. Strong, long, adherent spines arising from cardinal margin. Muscle impressions raised.

Brachial valve concave, lamellar tending to nodular structure. Area and pseudo-chilidium relatively large. Cardinal process inclined almost to horizontal; muscle impressions small at base of cardinal process.

Description.—The pedicle valve is firmly affixed to the underlying shell in most cases and hence the ornamentation is not known. In one specimen (Aus. Mus. F 38498) the shell is geniculate and the trail is ornamented by fine concentric lamellae and stout oblique spines. The area is wide and flat, in length half the width of the valve and with a width one-fifth of the length. The area is marked by longitudinal striations, interrupted medially by a triangular deltidium.

The cardinal margin bears very long, slender spines which are cemented to the host. These have a length much greater than the length of the shell, one spine extending 1.3 cm. from the margin. The spines occur in a matted group on the ears becoming more sparse towards the umbo; they arise perpendicular to the cardinal margin.

The teeth are strong, hollowed posteriorly to give a semi-ovoid cavity, and diverging. The muscle impressions take a tetrahedral form, one apex of the tetrahedron towards the umbo and beneath the area. The muscular apophyses are slightly concave, they appear smooth and divided into a greater and a lesser part by a narrow ridge parallel to and near their anterior margins. The edge separating them is a thickened ridge simulating a median septum. The anterior face of the tetrahedron is narrow, and has curved side edges, due to the concavity of the apophyses. Any other markings on the inside of the shell have been obliterated.

The brachial valve has the shiny lamellar structure characteristic of so many *Strophalosias*. Superimposed on these lamellae are concentric wrinkles extending over the entire surface of the valve. The wrinkles are irregular in intensity giving a general impression of a nobbly rather than a lamellar structure. It is possible, although no evidence of their presence can be seen on this specimen, that spines were developed over part of the visceral disc. Marginal spines were present as shown by the numerous pustules. The brachial valve is swollen below the umbo into a strongly convex semi-spherical region which, undergoing rapid change of curvature, becomes flat and so continuing across the visceral disc upturns marginally. The area of the valve has a width about half that of the pedicle area; the chilidium is triangular. If the valves are held in such a position that their height is vertical, the areas of both valves are in one horizontal plane.

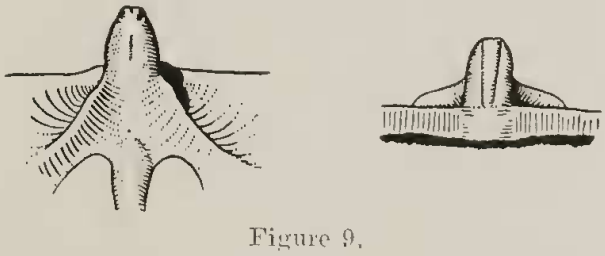

Figure 9.

Cardinal Process of **Etheridgina muirwoodae** n. sp. (×6).

The cardinal process is relatively large and is inclined almost at right angles to the area of the valves. It shows a characteristic trifid structure when viewed posteriorly, although the lateral arms adhere closely to the central

pillar. On each side of it are deep sockets each of which is bounded by a curved plate arising from the side of the cardinal process and making an angle with it of about 45°. A very short median septum is present, separating the muscle scars which lie close to the base of the cardinal process. These muscle impressions are not dendritic, nor do they show any division into anterior and posterior adductors. The brachial impressions are not preserved. Pitting is seen over some parts of the internal surface.

The dimensions of the shells are shown by the following table:—

Co-types.

	Conjoined valves.	Pedicle valves.		
Height	0·75	1·03+	1·10	0·58+
Maximum width	0·87	1·28+	1·41	0·92
Length of hinge-line	0·48	0·95	0·95	0·76

Variation within the species.—As may be expected in a closely adherent species the members of this species vary widely according to the nature of the host. The pedicle valve may be flat to highly convex (e.g. 10930); its area, though usually horizontal, may be highly inclined. It seems, too, that when the pedicle valve is closely adherent, it tends to assume the ornamentation of its host: thus, in G.S.W.A. 10930 B, where the host is a brachial valve of *Spirifer marconi* the pedicle valves exposed are corrugated to fit in between the striae. This feature is accentuated by weathering.

Comparison with other species.—It is with some trepidation that I have distinguished these specimens from other species of the genus, particularly as they had already been referred to *E. complectens* (Eth. fil.) by the author of that species. Their characters, however, are so distinct, that I have been forced to separate them. The specimens are larger and thicker-shelled forms than *E. complectens*; they possess relatively large and well-developed cardinal areas, strong teeth and characteristic muscular impression, in all these characters being distinct from *E. complectens*. The mode of attachment cannot be regarded as an important difference since, had the shells chosen a crinoid as host, it seems probable that the spines would encircle the stem, and we have as yet an insufficient number of specimens to say that they cannot or do not choose crinoid hosts.

The species heading of these specimens in Etheridge's description (1918, p. 253) is *Strophalosia complecteus*, but elsewhere in the text and in the explanation of figures he gives *S. complectens*. I have assumed therefore that the title name was due to a typographical error.

It is possible that this species is really the adherent form of *Strophalosia etheridgei* mihi. The structure of the brachial valves of the two species are remarkably similar, the variations seen, such as the higher position of the muscle impressions and the more inclined cardinal process in *E. muirwoodae* being probably modifications due to the assumption of a fixed habit. The external appearances of the two species differ only in the presence of spines in *E. muirwoodae* and this too may be due to the reason noted above.

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PLATE I.

Dictyoclostus callytharrensis n. sp.

Fig. 1. Brachial valve. Syntype. G.S.W.A. 1/4967 (b). (x $\frac{2}{3}$).

Fig. 2. Pedicle valve (x $1\frac{1}{3}$), to show ornamentation. G.S.W.A. 1/4654.

Fig. 3. Pedicle valve. Syntype. G.S.W.A. 1/4967 (b). (x $\frac{2}{3}$).

Fig. 4. Lateral view of Pedicle valve. U.W.A. 12400. (x $\frac{2}{3}$).

Fig. 5. Brachial valve (x $1\frac{1}{3}$), showing hinge-line and ginglimus. G.S.W.A. 1/4654.

Fig. 6. Hinge-line (x $1\frac{1}{3}$), to show ginglimus. Paratype. G.S.W.A. 1/4967 (a).

Fig. 7. Pedicle valve. U.W.A. 12400. (x $\frac{2}{3}$).

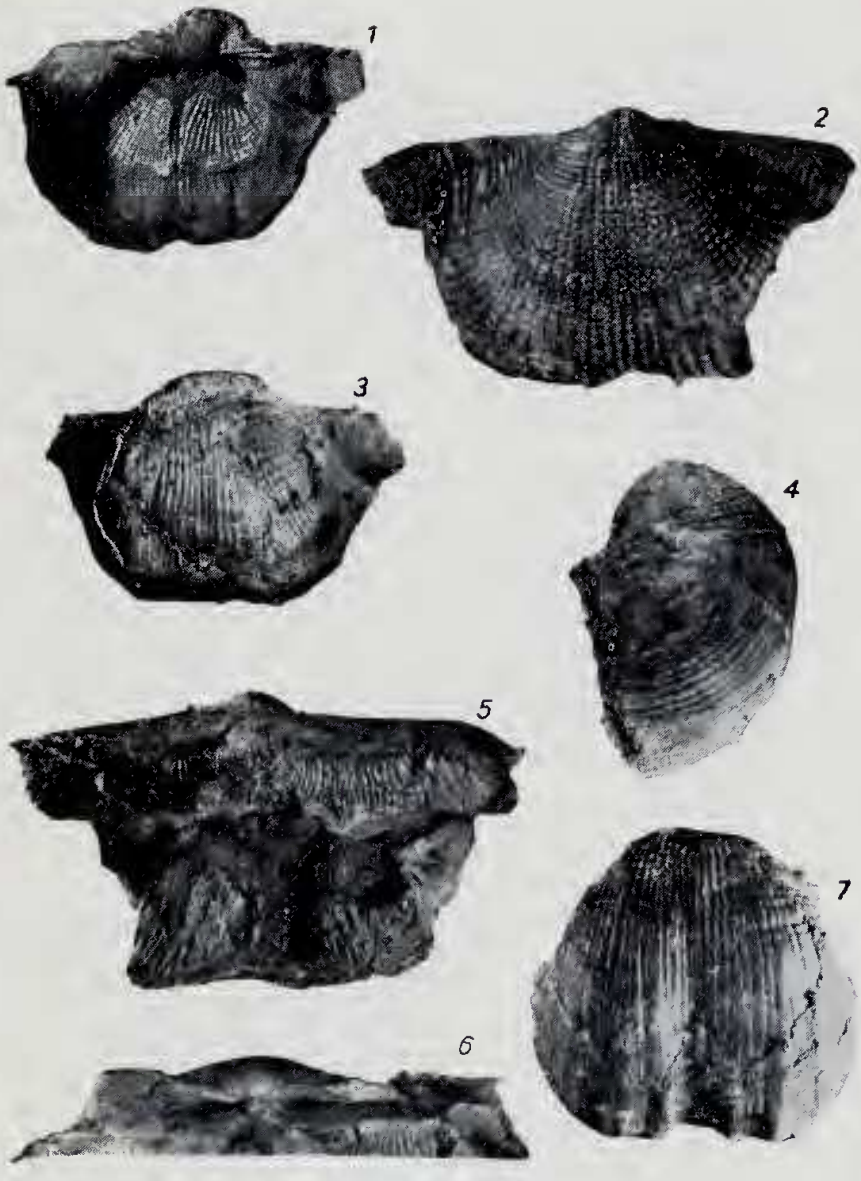

PLATE I.

PLATE II.

Fig. 1. **Dictyoclostus callytharrensis** n. sp. Pedicle valve (x $1\frac{1}{3}$). Paratype G.S.W.A. 1/4967 (a).

Figs. 2-4. **Dictyoclostus callytharrensis** var. **wadei.** n. var. Holotype. U.W.A. No. 20453. (x $\frac{2}{3}$).

2. Hinge-line and umbonal region.
3. Lateral view of holotype.
4. Pedicle valve of holotype.

Figs. 5-7. **Dictyoclostus gratiosus** (Waagen). Aus. Mus. F. 37569 (x $\frac{2}{3}$).

5. Pedicle valve.
6. Lateral view.
7. Brachial valve.

Figs. 8-9. **Dictyoclostus spiralis** (Waagen). Aus. Mus. F. 36514. (x $\frac{2}{3}$).

8. Pedicle valve.
9. Lateral view.

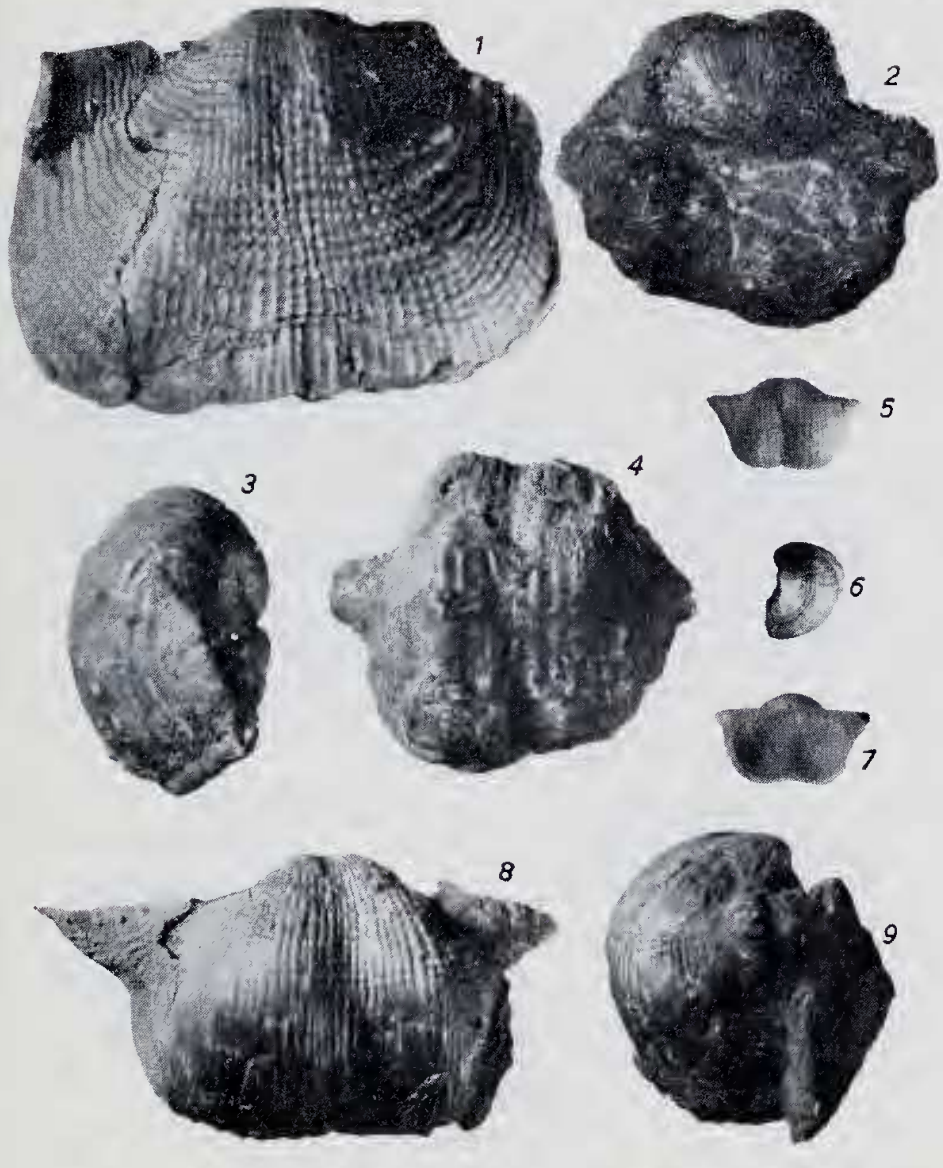

PLATE II.

PLATE III.

Figs. 1-2. **Linoproductus cancriniformis** var. **lyoni** n. var. Holotype. Aus. Mus. F. 36530. (x $\frac{2}{3}$).

1. Lateral view.
2. Pedicle and brachial valves.

Figs. 3-5. **Linoproductus cora** var. **foordi** (Eth. fil.). G.S.W.A. 5708b. (x $\frac{2}{3}$).

3. Pedicle valve.
4. Brachial valve.
5. Lateral view.

Fig. 6. **Waagenoconcha vagans** Reed. Brachial valve. U.W.A. 20459. (x $\frac{2}{3}$).

Figs. 7-9. **Waagenoconcha imperfecta** Prendergast.

7. Pedicle valve. U.W.A., 20454. (x $\frac{2}{3}$).
8. Brachial valve. U.W.A., 20454. (x $\frac{2}{3}$).
9. Umbonal region of pedicle valve. U.W.A., 20457. (x $\frac{2}{3}$).

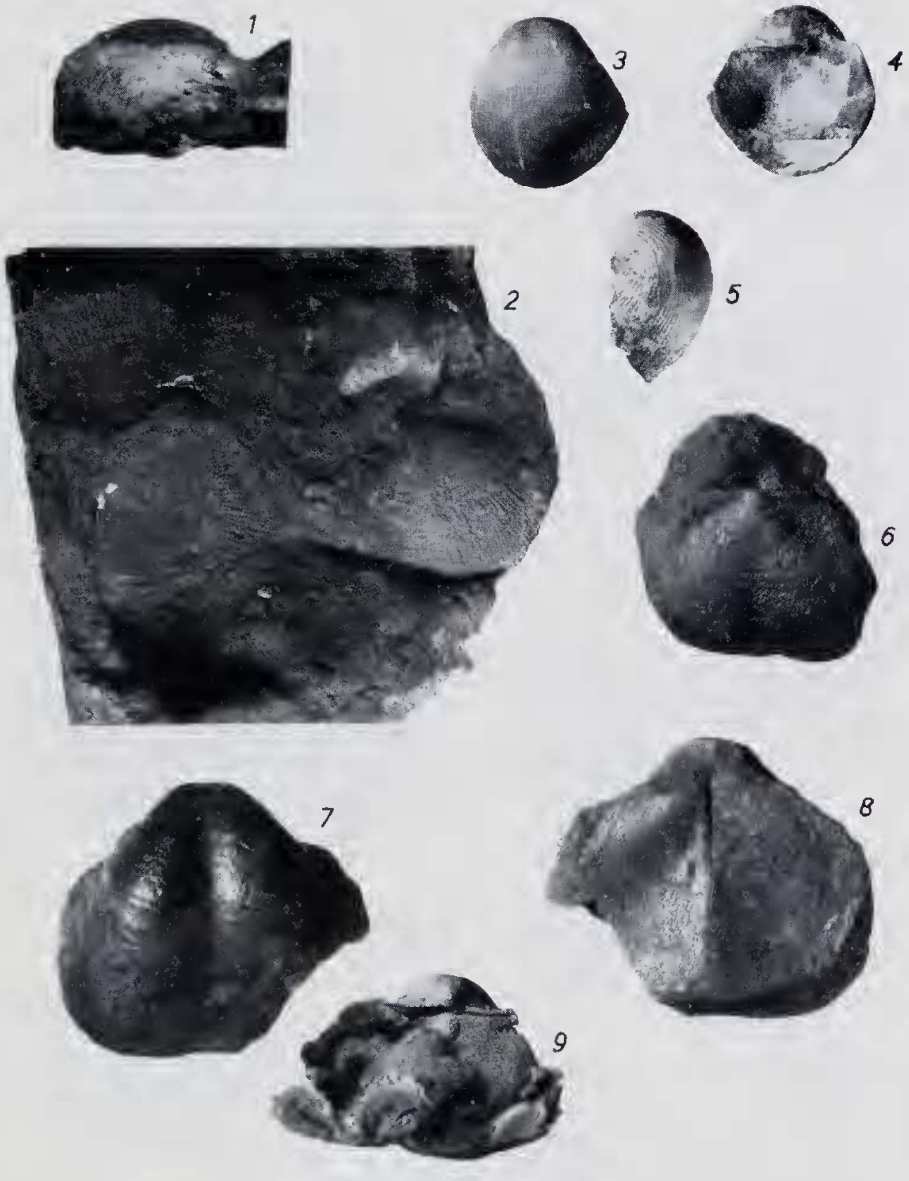

PLATE III.

PLATE IV.

Figs. 1-6. **Taeniothaerus subquadratus** (Morris).

1. Brachial valve, exterior. U.W.A. 12396.
2. Brachial valve, interior. U.W.A. 21247.
3. Interior of pedicle valve. U.W.A. 4786.
4. Pedicle valve, exterior. U.W.A. 20447.
5. Lateral view. U.W.A. 20447.
6. Hinge-line of crushed specimen. U.W.A. P. 21.

Figs. 7-10. **Aulosteges spinosus** Hosking.

7. Pedicle valve. Aus. Mus. F. 37710.
8. Lateral view showing recurved area. Aus. Mus. F. 37710.
9. Brachial valve. Aus. Mus. F. 38444.
10. Pedicle valve. Aus. Mus. F. 38444.

Figs. 11-13. **Krotovia spinulosa** (J. Sowerby). Aus. Mus. 38446.

11. Lateral view.
12. Pedicle valve.
13. Brachial valve.

All figures reduced to $\frac{3}{4}$ nat. size.

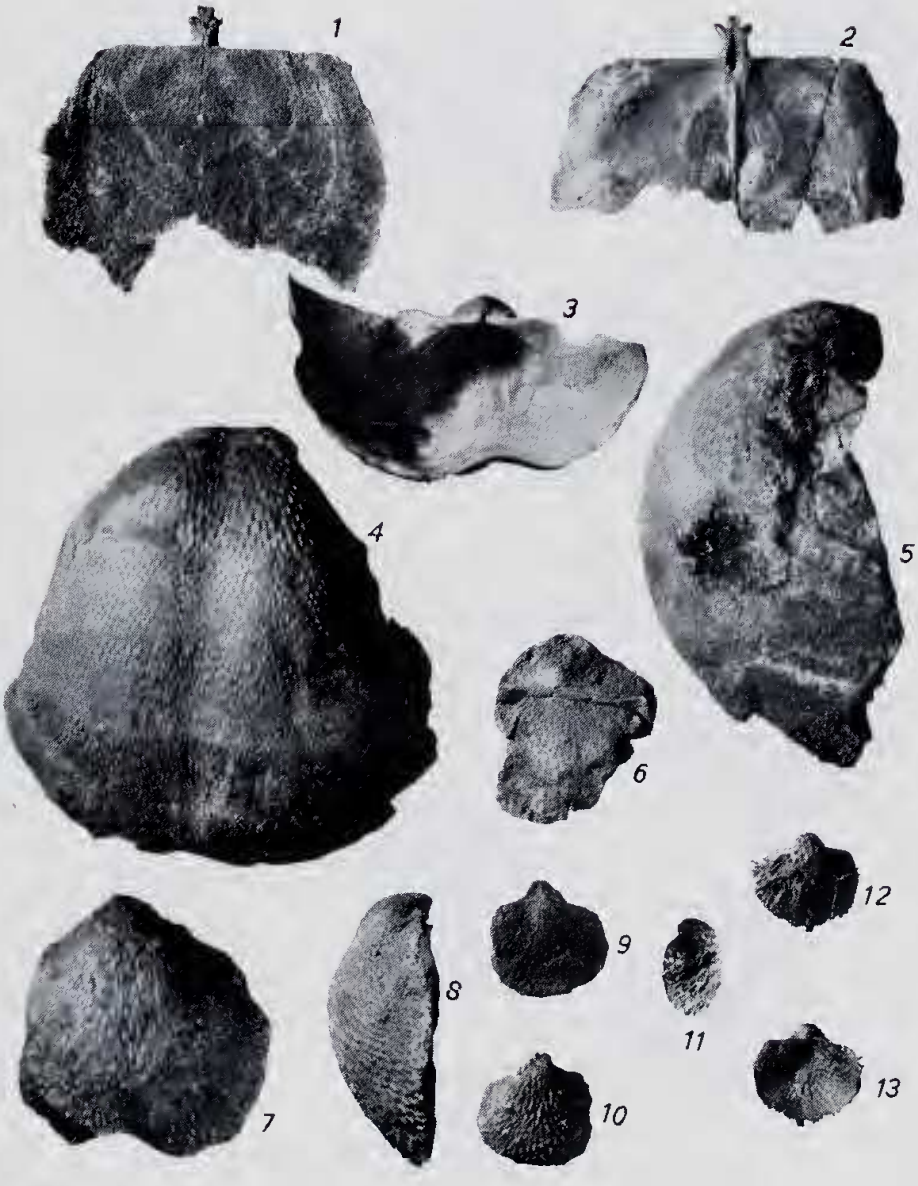

PLATE IV.

PLATE V.

Figs. 1-3. **Strophalosia** sp. cf. **Strophalosia beecheri** (Rowley). U.W.A., 20449. (x $\frac{2}{3}$).

1. Brachial valve.
2. Pedicle valve.
3. Lateral view.

Fig. 4. **Strophalosia clarkei** (Etheridge). Interior of brachial valve. Ans. Mus. F. 36235. (x $\frac{2}{3}$).

Figs. 5-12. **Strophalosia etheridgei** n. sp.

5. Brachial valve in limestone. U.W.A., 20247(a). (x $\frac{2}{3}$).
6. Pedicle valve (x $1\frac{1}{3}$). Syntype. G.S.W.A. 1/5242 (a).
7. Interior of pedicle valve (x $1\frac{1}{3}$). Syntype. G.S.W.A. 1/5242 (a).
8. Lateral view (x $1\frac{1}{3}$). Syntype. G.S.W.A. 1/5242 (a).
9. Brachial valve (x $1\frac{1}{3}$). Syntype. G.S.W.A. 1/5242 (a).
10. Interior of brachial valve (x $1\frac{1}{3}$). Syntype. G.S.W.A. 1/5242 (a).
11. Brachial valve in limestone (x $\frac{2}{3}$). U.W.A., 20247 (c).
12. Pedicle valve (x $\frac{2}{3}$). U.W.A., 20267.

Fig. 13. **Strophalosia gerardi** King. Holotype. Univ. Coll. Galway, I.F.S. No. F.C.D. 267. Brachial valve and hinge-line. (x $\frac{2}{3}$).

Figs. 14-15. **Strophalosia** sp. cf. **Strophalosia gerardi** King. (x $\frac{2}{3}$). U.W.A. 12399.

14. Pedicle valve.
15. Hinge-line of pedicle valve.

Figs. 16-17. **Strophalosia gerardi** King. Holotype. (x $\frac{2}{3}$).

16. Lateral view.
17. Pedicle valve.

Figs. 18-20. **Strophalosia Jukesi** Eth. fil.

18. External cast of brachial valve. (x $\frac{2}{3}$). U.W.A., 20266.
19. Internal cast of brachial valve. (x $\frac{2}{3}$). U.W.A. 20264.
20. Internal cast of pedicle valve. (x $\frac{2}{3}$). U.W.A. 20264.

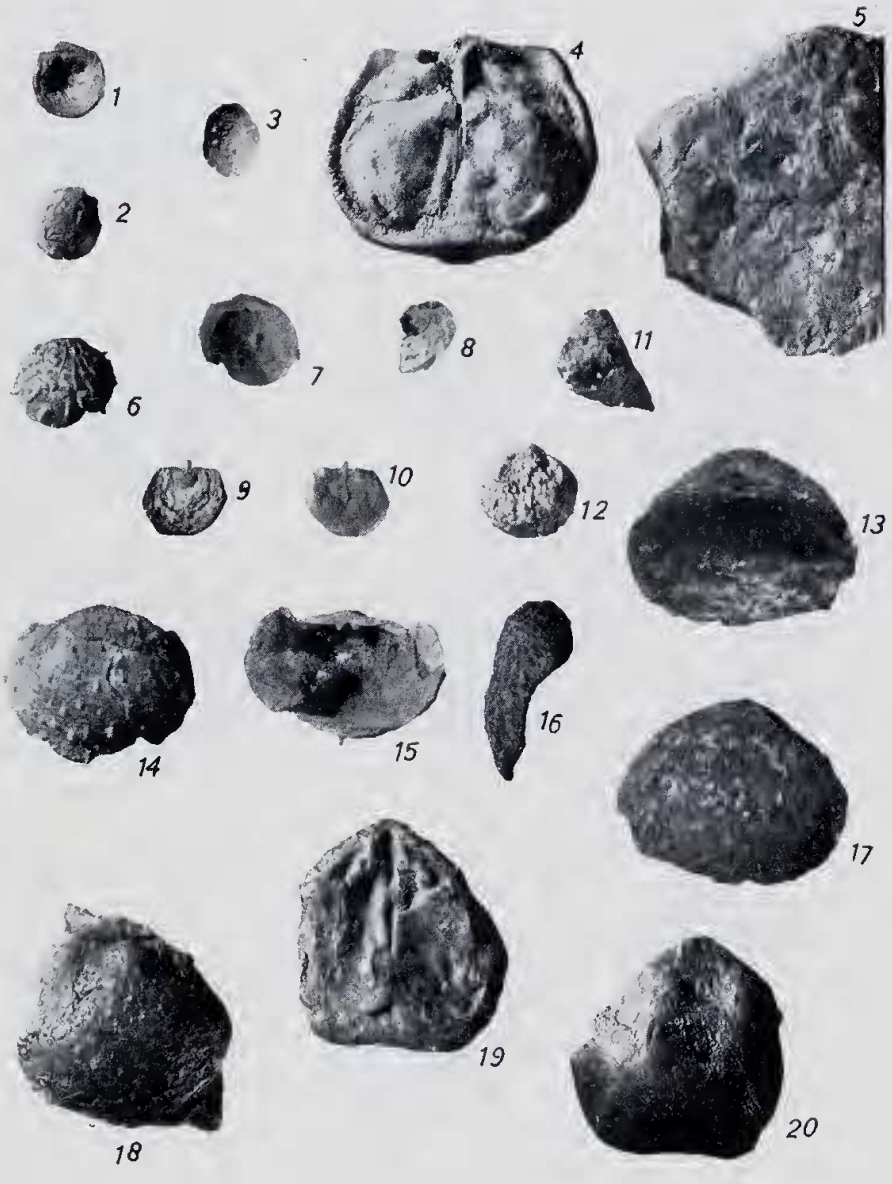

PLATE V.

PLATE VI.

Figs. 1-5. **Strophalosia kimberleyensis** n. sp.
1. Brachial valve. Holotype. U.W.A., 20452.
2. Pedicle valve. Holotype.
3. Lateral view. Holotype.
4. Interior of brachial valve. Paratype. U.W.A., 20455.
5. Interior of pedicle valve. Paratype. U.W.A., 20460.

Figs. 6-8. **Strophalosia multispinifera** n. sp. Holotype. U.W.A., 20458.
6. Lateral view.
7. Hinge-line.
8. Pedicle valve.

Fig. 9. **Strophalosia tenuispina** Waagen. Pedicle valve. U.W.A., 20451.

Figs. 10-12. **Strophalosia** sp. A. U.W.A., 20448.
10. Interior of pedicle valve.
11. Pedicle valve.
12. Lateral view.

Fig. 13. **Etheridgina complectens** (Eth. fil.). Syntype. Royal Scottish Museum No. 5080.

Figs. 14-15. **Etheridgina muirwoodae** n. sp. Syntypes. Aus. Mus. F. 16699.
14. Interior of pedicle valve and exterior of brachial valve.
15. Interior of pedicle valve.

All figures reduced to $\frac{2}{3}$ nat. size.

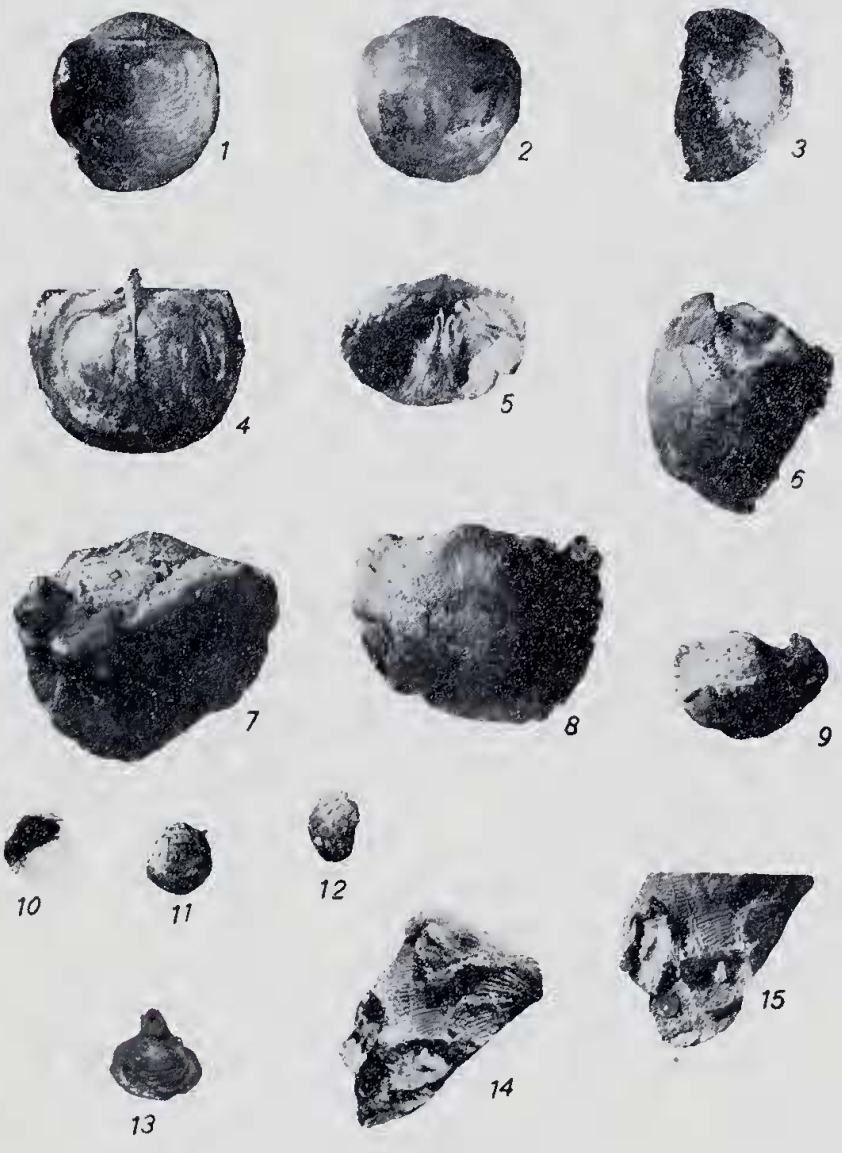

PLATE VI.

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